3.0 REGIONAL GEOMORPHIC CHANGE

Nearshore sediment transport processes influence the evolution of shelf sedimentary environments to varying degrees depending on temporal and spatial response scales. Although micro-scale processes, such as turbulence and individual wave orbital velocities, determine the magnitude and direction of individual grain motion, variations in micro-scale processes are considered noise at regional-scale and only contribute to coastal response in an average sense. By definition, regional-scale geomorphic change refers to the evolution of depositional environments for large coastal stretches (10 km or greater) over extended time periods (decades or greater) (Larson and Kraus, 1995). An underlying premise for modeling long-term morphologic change is that a state of dynamic equilibrium is reached as a final stage of coastal evolution. However, the interaction between the scale of response and forces causing change may result in a net sediment deficit or surplus within a system, creating disequilibrium. This process defines the evolution of coastal depositional systems.

Topographic and hydrographic surveys of coastal and nearshore morphology provide a direct source of data for quantifying regional geomorphology and change. Historically, hydrographic data have been collected in conjunction with regional shoreline position surveys by the U.S. Coast and Geodetic Survey (USC&GS); currently Office of Coast Survey of the National Ocean Service [NOS], National Oceanic and Atmospheric Administration [NOAA]). Comparison of digital bathymetric data for the same region but different time periods provides a method for calculating net sediment movements into (accretion) and out of (erosion) an area of study. Coastal scientists, engineers, and planners often use this information for estimating the magnitude and direction of sediment transport, monitoring engineering modifications to a beach, examining geomorphic variations in the coastal zone, establishing coastal erosion setback lines, and verifying shoreline change numerical models.

The purpose of this portion of the study is to document patterns of geomorphic change to quantify the magnitude and direction of net sediment transport over the past 100 to 120 years. These data, in combination with wave and current measurements and model output, provide a temporally integrated technique for evaluating the potential physical impacts of offshore sand mining on sediment transport dynamics.

3.1 SHORELINE POSITION CHANGE

Creation of an accurate map is always a complex surveying and cartography task, but the influence of coastal processes, relative sea level, sediment source, climate, and human activities make shoreline mapping especially difficult. In this study, shoreline surveys were used to define landward boundaries for bathymetric surfaces and to document net shoreline movements between specified time periods. Consequently, net change results can be compared with wave model output and nearshore sediment transport simulations to evaluate cause and effect. Results integration provided a direct method of documenting potential environmental impacts related to sand mining on the OCS.

3.1.1 Previous Studies

The present study area is located on the central east coast of Florida, bounded to the north by False Cape and to the south by Jupiter Inlet (Figure 3-1). The continental shelf narrows from a maximum width of about 48 km near Cape Canaveral to a minimum of about 16 km in the southern extent of the study area as it merges with the Florida-Hatteras slope. This reduction in shelf width is accompanied by a distinct increase in shelf steepness (Field and Duane, 1974). Beaches along this region of the east coast of Florida are composed primarily of siliceous sand and sandy gravel mixed with large quantities of shell fragments (Figure 3-2; McLaren and Hill, 2002). South of Port Canaveral, beach sediment becomes increasingly coarse and shell-enriched in response to the existence of local coquina outcrops (Field and Duane, 1974). Sediment is eroded from offshore shoals and northern beaches and is transported to southern beaches as southward-directed littoral transport. Source material is added locally into the littoral drift system from large exposures of coquinoid limestone that are present from 1 m below mean low water (MLW) to the berm crest between Cocoa and Canova Beaches (Field and Duane, 1974). The shoreline in this region exists as five barrier islands separated from each other by inlets and from the mainland by the Intracoastal Waterway, which includes the Banana and Indian Rivers. Each inlet is armored with rock jetties to control channel migration. Maintenance dredging has been practiced periodically at all entrances during the study time period to maintain channel navigability. Some of the greatest shoreline changes that occur along the outer coast of Florida were the result of interrupted longshore transport at these inlets. Additionally, navigation structures used to control channel migration and shoaling may result in erosion and deposition “hot spots” along beaches adjacent to inlets. Often, material dredged from the channels has been recycled back into the littoral transport system through placement on beaches immediately south of entrances.

Numerous studies have been completed by Federal, State, and local agencies to evaluate shoreline evolution for beach management and protection purposes. The Florida Beach Erosion Control Program, implemented in 1964, created three interrelated programs administered by the Florida Department of Environmental Protection (FDEP), including the Coastal Construction Control Line (CCCL) program, the Beach Erosion Control Program, and the Coastal Construction Program. In support of the CCCL program, historical shoreline positions for the entire coast of Florida were digitized and developed for the Florida Department of Natural Resources (DNR) Division of Beaches and Shores historical shoreline database (Foster, 1992). This database includes all historical USC&GS topographic sheets from the 1850s to the 1980s (Demirpolat and Tanner, 1991). In addition, aerial photography and beach profiles surveyed from fixed DNR survey points (“R” monuments) have been added to the database. R-monuments are spaced at approximately 300 m along the entire Florida coast, and profiles have been surveyed periodically by the Coastal Data Acquisition System since the early 1970s. Initial data collection efforts in support of the CCCL program were implemented on a county-by-county basis, with emphasis on beach protection and inlet management on a county-wide scale. In the five counties that make up the present study area (Brevard, Indian River, St. Lucie, Martin, and Palm Beach), shore protection projects have been implemented since the late 1950s and have included beach nourishment along various segments of coast (Figure 3-3).

In 1986, the FDEP, as part of the Beach Erosion and Control Program, developed a comprehensive beach management planning program designed to identify areas of shoreline erosion within the State and seek mitigation strategies. In the five counties that make up the present study area, a total of 86 km of shoreline currently is identified as critically eroded (Florida DEP Office of Beaches and Coastal Systems, 1999). Critical erosion areas for each county are summarized in Figure 3-4. For all counties, erosion is attributed to winter northeast storms, tropical storms, hurricanes, and the effects of inlets. A large component of areas designated as critically eroded exist immediately downdrift of entrances. Inlet management plans have been developed for all entrances within the study area. A summary of inlet development and maintenance information is presented in Table 3-1.

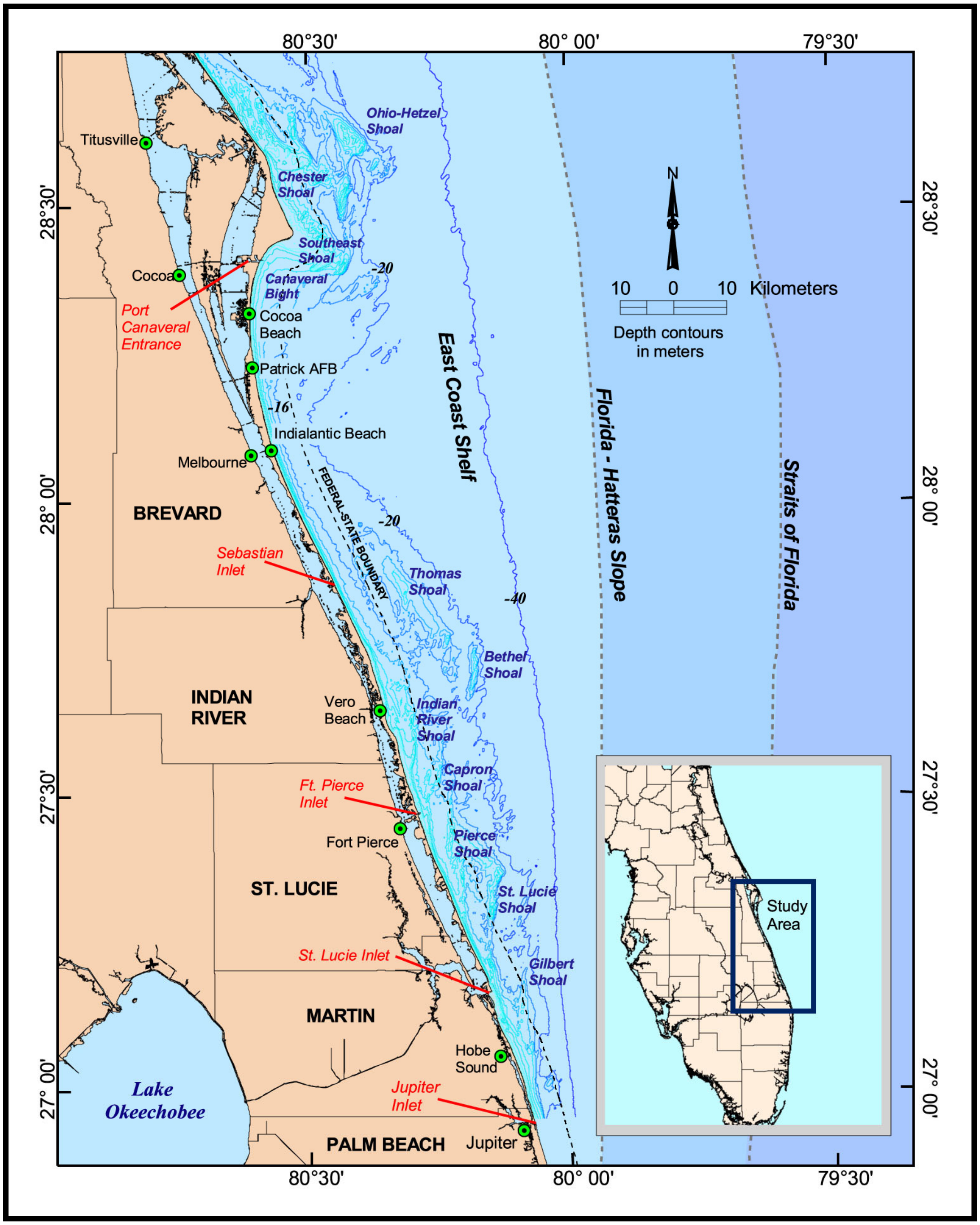

Figure 3-1. Study location diagram.

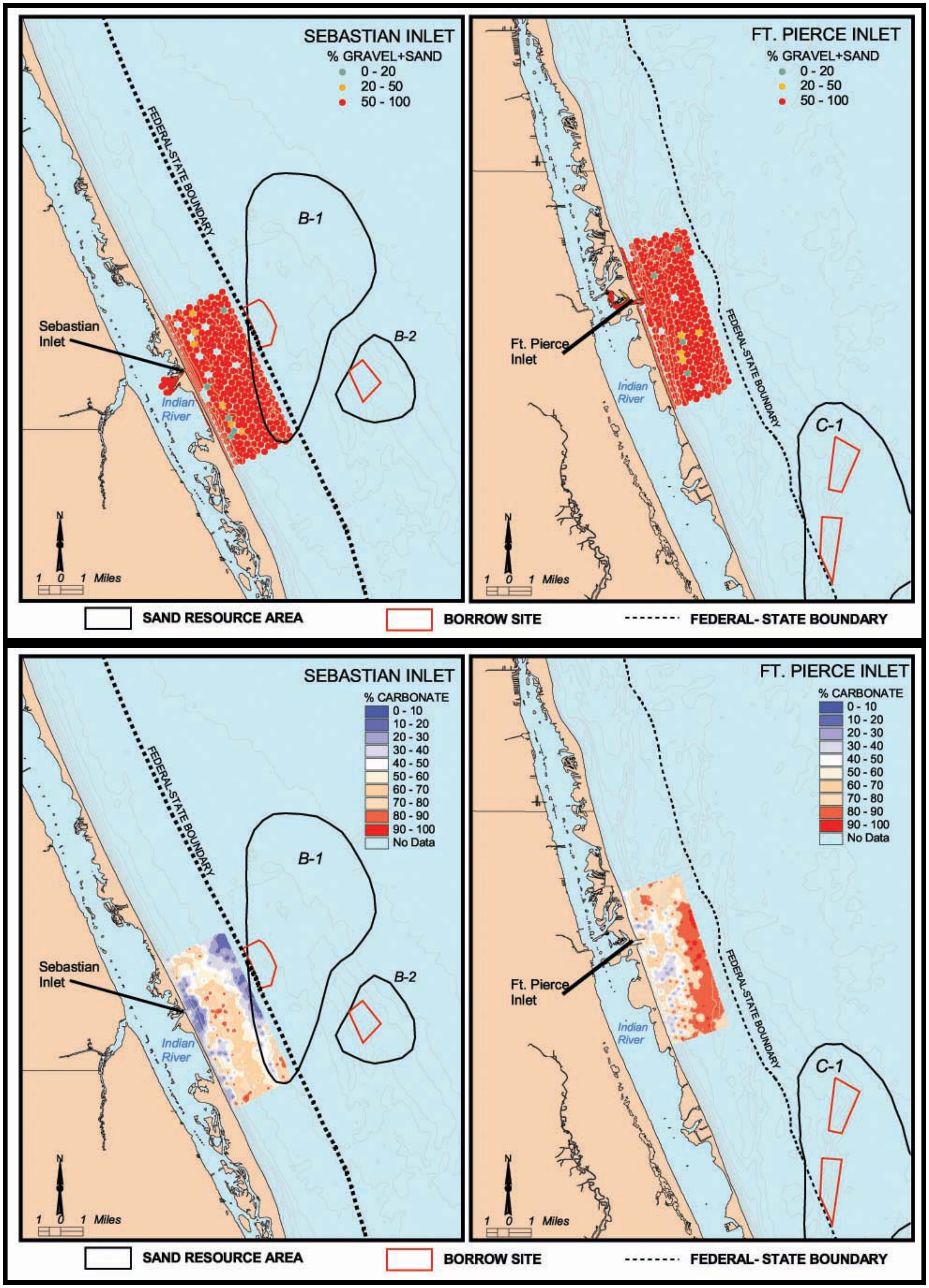

Figure 3-2. Sediment grain-size and carbonate distribution at Ft. Pierce and Sebastian Inlets (data collected by GeoSea Consulting Ltd. in December 2001).

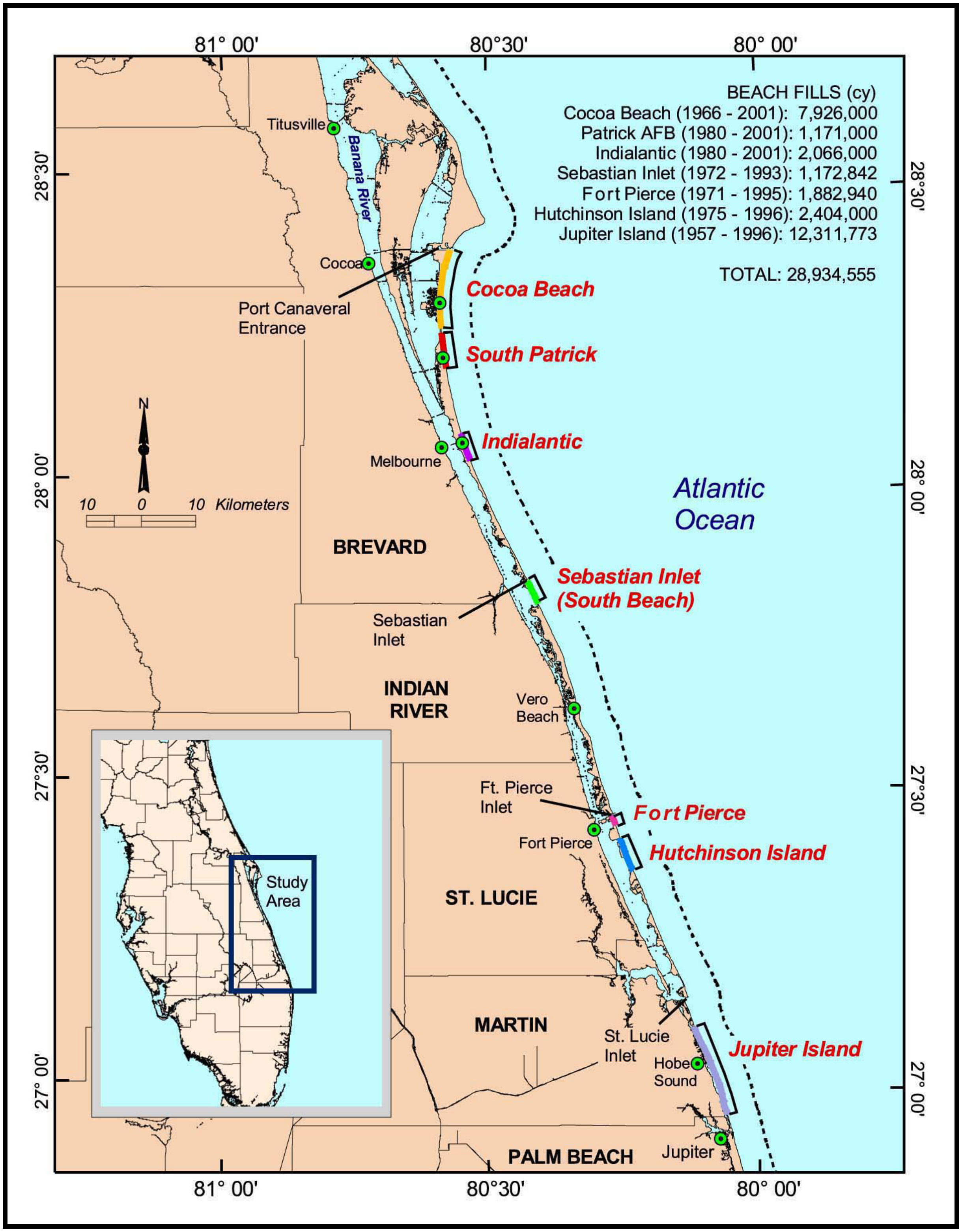

Figure 3-3. Beach fill activities between 1957 and 2001.

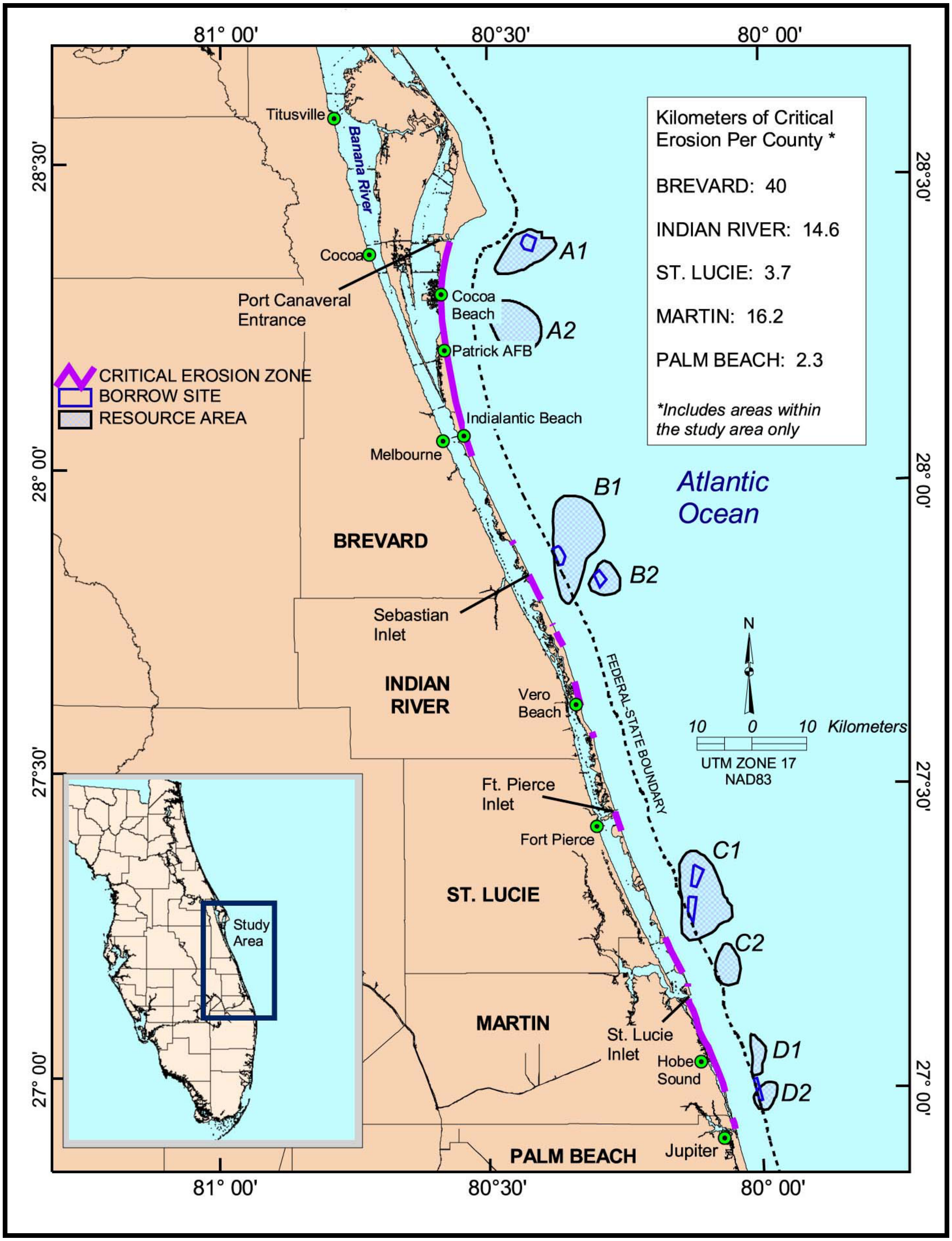

Figure 3-4. Areas designated by the Florida Department of Environmental Protection as Critical Erosion Zones.

Table 3-1. Summary of inlet management activities.

Inlet	Initial Development	Maintenance Dredging	South Side Beach Nourishment	Reference
Port Canaveral Inlet	1951 to 1954	Currently maintained to -46 ft MLW. Maintenance dredging done every 12 to 18 months.	Since 1966 some sediment from inlet and some from offshore.	Florida DEP and Canaveral Port Authority (1996)
Sebastian Inlet	1919 to 1924	Maintenance dredging of channel and sand trap occurs periodically. Inlet management plan in March 2000 established annual bypassing objective of 56,000 m^3 (70,000 cy).	Additional material from an upland source also is occasionally placed on downdrift beaches.	Florida DEP Office of Beaches and Coastal Systems (2000)
Ft. Pierce Inlet	1920 to 1921	Initially dredged in 1938 and deepened in 1996. Maintenance dredging conducted on a biannual basis since 1978.	Since 1978, disposal of inlet material.	Florida DEP and St. Lucie County (1997)
St. Lucie Inlet	1916 to 1929	Current Federally authorized features were completed in 1982. Maintenance dredging conducted at approximately 4-year intervals.	Dredged material is placed within a 1.6 km segment of beach.	Florida DEP and Martin County (1995)
Jupiter Inlet	1922	Maintenance dredging of the channel and sand trap occurs generally on an annual basis. Approximately 57,000 m^3 (75,000 cy) estimated for bypassing on an annual basis.	Sediment is bypassed annually and is periodically supplemented by sediment dredged from the Intracoastal Waterway.	Florida DEP and Jupiter Inlet District (1997)

Recent beach protection and sediment management efforts in Florida have shifted from a county-wide basis to a more regional approach. The Statewide Coastal Monitoring Program was implemented in 2000 with the objective of acquiring monitoring data on a regional scale. The FDEP Office of Beaches and Coastal Systems (OBCS) has developed a regional data collection plan that identified four coastal regions within which comprehensive data collection will occur on a recurring annual cycle (Leadon, 2002). Data collection began as part of this program in 2000 and is scheduled to continue annually through 2005. The extent of the present study area is in the southeast region and was scheduled for data collection in 2002. Data collected include digital aerial photography, FDEP beach profile surveys, and wave data (Leadon et al., 2001; data available at http://www.dep.state.fl.us/beaches/data/coastmon.htm). Of the recently collected data, aerial photography, beach profile, and wave data were used as part of this study. Aerial photos were used to delineate the high-water shoreline in Martin and Palm Beach Counties to complete the most recent composite shoreline (1996/2002). Beach profile data were evaluated to assist in determining berm crest elevation for developing bathymetric surfaces, and wave gage data from the nearshore wave gage installed at Melbourne Beach were incorporated in the waves section of this report. Recent data collection efforts by the FDEP also include sediment sampling. About 700 grab samples were taken in December 2001 by GeoSea Consulting Ltd. to characterize sediment grain size, composition, and transport processes at Fort Pierce and Sebastian Inlets (McLaren and Hill, 2002). Data from this collection effort were used for evaluating sediment characteristics adjacent to sand resource areas.

3.1.2 Shoreline Position Data Base

Eight outer coast high-water shoreline surveys were used to quantify historical shoreline change between 1878/83 and 2002 (Table 3-2). The first four surveys were conducted by the USC&GS in 1877/83, 1928, 1942/48, and 1970. Digital data for these topographic field surveys (T-sheets) and tide-coordinated photographic surveys (TP-sheets; 1970) were compiled from historical maps by Demirpolat and Tanner (1991), and were obtained from the FDEP website in AutoCAD drawing (dwg) format. The remaining four surveys were completed in 1996, 2000, and 2002 (differential global positioning system [DGPS] field surveys and aerial photography). Because individual survey extents did not encompass the entire study area, the four data sets were combined to create a composite shoreline representing the time period 1996/2002. Three of these surveys are DGPS field surveys conducted in May 1996, June 2000, and June 2002, and the fourth is a shoreline interpreted from 2002 orthorectified aerial photography. The DGPS surveys were conducted by Applied Coastal using a Trimble Pro/XR differential GPS, and the aerial photography was obtained from the FDEP website. The high-water shoreline was interpreted from 2002 orthorectified aerial photography by Applied Coastal personnel. Horizontal position of the high-water shoreline for DGPS surveys was determined visually using a hierarchy of criteria dependent on morphologic features present on the subaerial beach. The primary criterion was a well-marked limit of uprush by waves associated with high tide. This generally was recognized on the beach as the berm crest (Figure 3-5). If a berm crest did not exist, a debris line could usually be identified, below which the beach face was smooth from the action of wave swash and backwash. The criteria adopted are consistent with those used by field topographers and photo interpreters in developing NOS T- and TP-sheet shorelines (Swainson, 1928; Shalowitz, 1964). All high-water shoreline data were projected into a common horizontal coordinate system and datum, in this case Universal Transverse Mercator (UTM) Zone 17N, North American Datum of 1983 (NAD83).

When determining shoreline position change, all data contain inherent uncertainties associated with field and laboratory compilation procedures. These uncertainties should be quantified to gauge the significance of measurements used for engineering/research applications and management decisions. Table 3-3 summarizes estimates of potential error for the shoreline data sets. Because individual errors represent standard deviations, root-mean-square (RMS) error estimates are calculated as a realistic assessment of combined potential error.

Positional errors for each shoreline can be calculated using the information in Table 3-3; however, change analysis requires comparing two shorelines from the same geographical area but different time periods. Table 3-4 summarizes potential errors associated with change analyses computed for specific time intervals. As expected, maximum positional errors are aligned with the oldest shorelines (1877/83, 1928, and 1948) at smallest scale (1:20,000), but most change estimates for the study area document shoreline advance or retreat greater than these uncertainty estimates.

3.1.3 Historical Change Trends

Regional change analyses provided an assessment of shoreline response for comparison with predicted changes in wave-energy focusing at the shoreline resulting from potential offshore sand dredging activities. They differ from previous qualitative analyses in that continuous measurements of shoreline change are provided at 50-m alongshore intervals for the period 1877/83 to 2002. As such, model results (wave and sediment

Table 3-2. Florida shoreline source data characteristics.

Date	Data Source	Comments and Map Numbers
1877/83	USC&GS Topographic Maps (1:20,000)	First regional survey completed with standard engineering techniques. 1877 - Cape Canaveral to Cocoa Beach (T-sheets 1450a, 1450b). 1878 - Indialantic to Sebastian Inlet (T-sheets 1460, 1478). 1880/82 - Sebastian Inlet to Fort Pierce Inlet (T-Sheets 1544, 1630). 1883 - Fort Pierce to Jupiter Inlets (T-Sheets 1650, 1652, 1640).
1928	USC&GS Topographic Photomaps (1:20,000)	Second regional survey completed throughout study area. All maps produced from interpreted aerial photography. Cape Canaveral to Jupiter Inlet.
1942/48	USC&GS Topographic Photomaps (1:20,000)	All maps produced from interpreted aerial photography. 1942 - St. Lucie Inlet to Jupiter Inlet (T-sheets 8411, 8412, 8413, and 8414). 1946 - Wabasso to St. Lucie Inlet (T-sheets 8841, 8842, 8844, 8845). 1947 - 4 miles north of Cocoa Beach to Wabasso (T-sheets 8880, 8882, 8884, 8886, 8888). 1948 - False Cape to 4 miles north of Cocoa Beach (T-sheet 9174).
1970	USC&GS Topographic Photomaps in cooperation with the State of Florida (1:10,000)	All photomaps produced from interpreted aerial photography. (TP-sheets 135, 136, 138, 140, 142, 143, 145, 146, 147, 149).
1996	DGPS Survey (1:1)	North Boundary of Cape Canaveral National Seashore to Sebastian Inlet. Data collected by Applied Coastal using a Trimble Pro/XR.
2000	DGPS Survey (1:1)	North of Sebastian Inlet to north of Fort Pierce Inlet. Data collected by Applied Coastal using a Trimble Pro/XR.
2002	DGPS Survey (1:1)	South jetty of Port Canaveral to the north jetty of Sebastian Inlet.
2002	Orthorectified Aerial Photography	North of Fort Pierce Inlet to the southern border of Martin County. Aerial photos obtained from the FDEP website; high-water shoreline interpreted by Applied Coastal personnel.

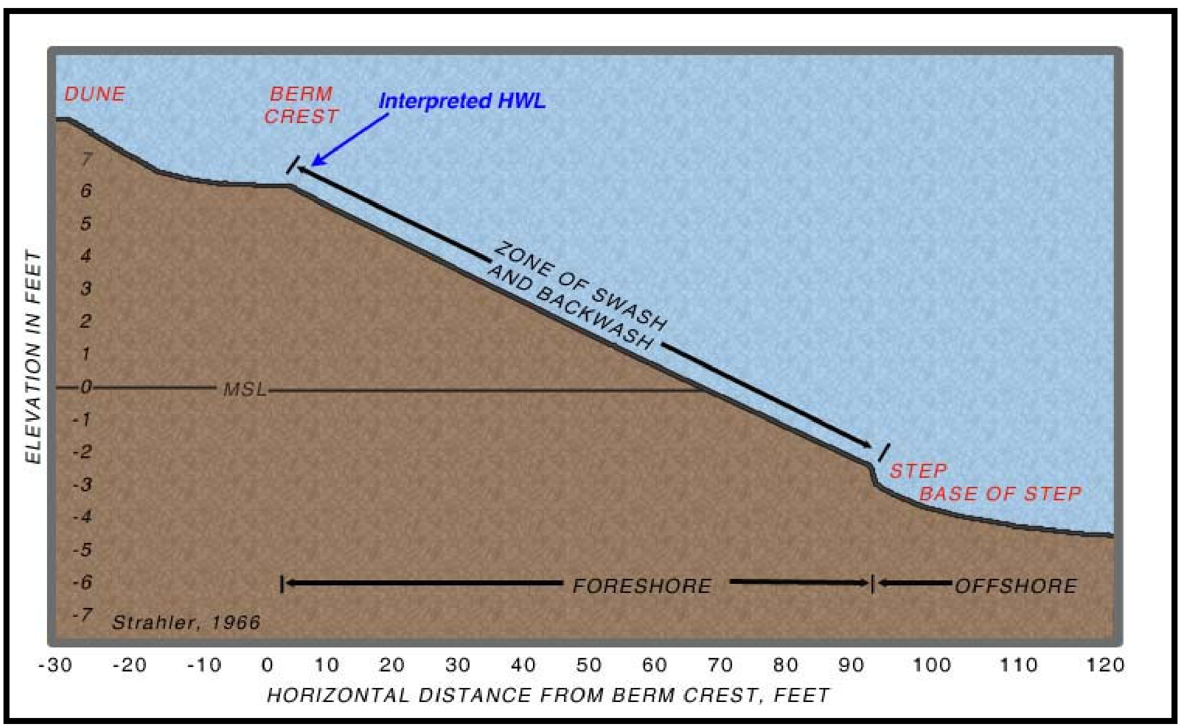

Figure 3-5. High-water shoreline position classification referenced to the beach berm crest.

Table 3-3. Potential error estimates associated with Florida shoreline position surveys.

Traditional Engineering Field Surveys (1877/83 shoreline)		
Location of rodded points	±1 m	
Location of plane table	±2 to 3 m	
Interpretation of high-water shoreline position at rodded points	±3 to 4 m	
Error due to sketching between rodded points	up to ±5 m	
Cartographic Errors (1877/83, 1928, 1942/48, and 1970)	**Map Scale**	
	1:10,000	1:20,000
Inaccurate location of control points on map relative to true field location	up to ±3 m	up to ±6 m
Placement of shoreline on map	±5 m	±10 m
Line width for representing shoreline	±3 m	±6 m
Digitizer error	±1 m	±2 m
Operator error	±1 m	±2 m
Historical Aerial Surveys (1928, 1942/48, and 1970)	**Map Scale**	
	1:10,000	1:20,000
Delineating high-water shoreline position	±5 m	±10 m
DGPS Surveys (1996, 2000, and 2002 shorelines)		
Delineating high-water shoreline	±1 to 3 m	
Position of measured points	±2 to 5 m (specified) ±1 to 3 m (field tests)	
Digital Aerial Photo Surveys (2002 shoreline)		
Delineating high-water shoreline	±5 m	
Aerial photo registration error	±1 m (RMS error report)	
Sources: Shalowitz, 1964; Ellis, 1978; Anders and Byrnes, 1991; Crowell et al., 1991.		

Table 3-4. Maximum root-mean-square potential error for Florida shoreline change data.

Year	1928	1942/48	1970	1996-2002 DGPS	2002 Aerial
1877/83	±22.6[1]	±22.6	±22.6	±16.3	±16.0
	(±0.5)[2]	(±0.3)	(±0.3)	(±0.1)	(±0.1)
1928		±23.7	±18.7	±17.7	±17.5
		(±1.2)	(±0.5)	(±0.3)	(±0.3)
1942/48			±18.7	±17.7	±17.5
			(±0.5)	(±0.3)	(±0.3)
1970				±10.2	±9.8
				(±0.4)	(±0.3)

[1] Magnitude of potential error associated with high-water shoreline position change (m).
[2] Rate of potential error associated with high-water shoreline position change (m/yr).

transport) at discrete intervals along the coast can be compared with historical data to develop process/response relationships for evaluating potential impacts. The following discussion focuses on incremental changes in shoreline response (1877/83 to 1928, 1928 to 1948, 1948 to 1970, and 1970 to 1996/2002) relative to net, long-term trends in the study area (1877/83 to 1970 and 1877/83 to 1996/2002).

3.1.3.1 1877/83 to 1928

The time period 1877/83 to 1928 summarized net shoreline change relative to natural coastal processes and human-induced changes at Sebastian, Fort Pierce, and St. Lucie Inlets. Variation in shoreline response associated with south-directed net longshore transport and construction of entrance jetties is visible throughout the study area during this time period. Shoreline change along ocean beaches from the northern limit of the study area to immediately north of Cape Canaveral (a distance of about 5 km) illustrated continuous erosion due to northeast storm impacts and south-directed longshore transport. Calculated recession rates ranged from 0.3 to 2.0 m/yr, with an average recession rate of 1.6 m/yr. This trend showed a distinct reversal along the shoreline south of this area for beaches adjacent to the Canaveral Bight. During this time period, the shoreline from the northern tip of Cape Canaveral to approximately 20 km south showed the greatest amount of deposition over the entire study area as substantial quantities of sand being transported from the north. South of this point for about 72 km (near Vero Beach), shoreline response was characterized by alternating zones of minor erosion and accretion, with most change exhibiting erosion. Greatest changes along this stretch of shoreline were associated with the creation of Sebastian Inlet between 1919 and 1924. A maximum erosion rate of 1.2 m/yr was recorded about 460 m south of the entrance, with the maximum accretion rate of 0.7 m/yr existing immediately north of the inlet (Figure 3-6). The shoreline south of this point for the next 19 km was primarily depositional, with some areas of erosion. Construction of jetties at Fort Pierce Inlet between 1920 and 1921 caused shoreline change similar to that observed at Sebastian Inlet, with deposition observed along the north side of the entrance and erosion to the south. Variation in response within this 19-km length of shoreline was more than twice the variation in rates observed immediately to the north. Recession rates varied to a maximum of about 1.5 m/yr, and deposition rates were less than about to 2.9 m/yr. From a point just south of Fort Pierce Inlet to the southern limit of the study area at Jupiter Inlet, the shoreline exhibited almost continuous erosion. This area showed the greatest amount of shoreline recession over the entire study area, with a maximum rate of about 16.8 m/yr associated with the development of St. Lucie Inlet between 1916 and 1929. Erosion rates remained high from St. Lucie Inlet south for about 11 km, where the shoreline became more stable and alternated between minor erosion and accretion to Jupiter Inlet.

3.1.3.2 1928 to 1948

Between 1928 and 1948, maximum rates of shoreline advance and recession again were observed at beaches along the south shore of Cape Canaveral and to the south of St. Lucie Inlet, respectively. Overall, shoreline response illustrated an increase in net deposition from that observed during the previous time period (Figure 3-7). The shoreline north of Cape Canaveral experienced erosion followed by an extensive zone of deposition along beaches adjacent to Canaveral shoals, similar to trends observed in this region between 1877 and 1928. This indicates that south-directed longshore transport continued to dominate shoreline response in this region. Recession rates on the northern side of Cape Canaveral ranged up to 7.4 m/yr, similar to those observed during the previous time period. Unlike shoreline change trends observed between 1877 and 1928, shoreline advance was dominant south of Cape Canaveral for about 153 km to St. Lucie Inlet between 1928 and 1948, with only minor erosional aberrations along small stretches of coast. Similar change trends were documented at Fort Pierce Inlet, with deposition north of the entrance and erosion to the south (Figure 3-7). Shoreline advance also was prominent along the north side of St. Lucie Inlet, with a maximum rate of 8.9 m/yr due to construction of a jetty along the north side of the inlet around 1928. South of St. Lucie Inlet, net shoreline recession was dominant for about 10 km. Erosion during this period (maximum of 7.1 m/yr), while smaller in magnitude than that observed between 1877/83 and 1928, was similar to that observed north of Cape Canaveral. South of this erosion zone, the change trend again returned to deposition.

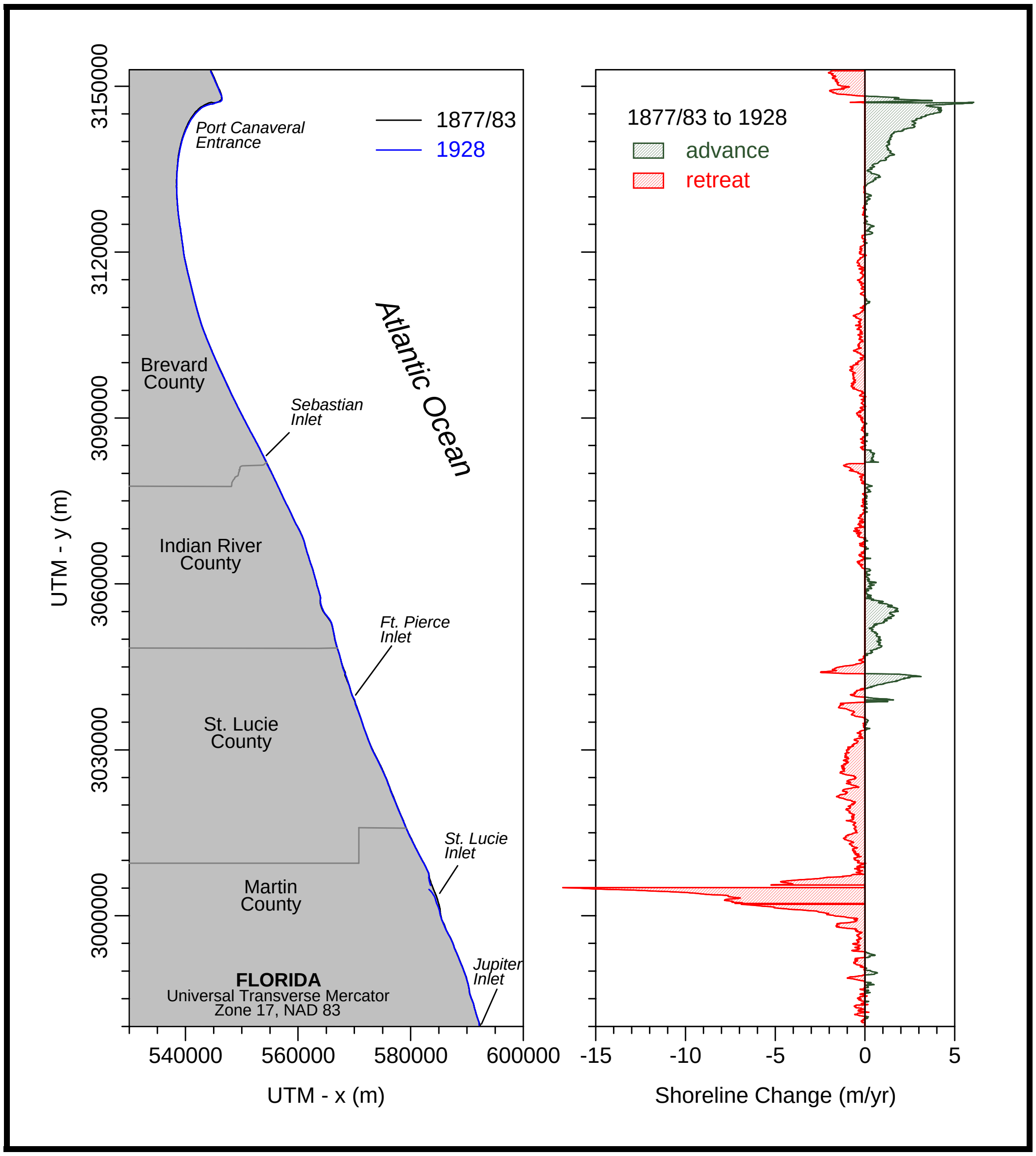

Figure 3-6. Shoreline position and change between False Cape and Jupiter Inlet, FL, 1877/83 to 1928.

3.1.3.3 1948 to 1970

Shoreline change between 1948 and 1970 illustrated similar overall trends to those observed during the previous 70 years. Maximum deposition again was observed along beaches on the south side of Cape Canaveral, and maximum erosion was located south of St. Lucie Inlet (Figure 3-8). The largest difference from the previous 70 years of shoreline change was observed north and south of Port Canaveral, which was developed as a Federal navigation project between 1951 and 1954 (Kraus et al., 1999). The beach north of the entrance experienced increased deposition immediately north of the north jetty to a maximum rate of 9.5 m/yr, and the south side of the entrance experienced shoreline recession as south-directed sand transport was blocked by the structures and the inlet. The erosion zone was limited to about 2.4 km south of the entrance, at which point shoreline response began to exhibit similar trends to those observed from 1877/83 to 1928 with overall fluctuations in erosion and deposition being slightly greater (Figure 3-8). Changes at four of the five entrances were similar to those observed in previous years, with deposition to the north and erosion to the south of Sebastian, Fort Pierce, and St. Lucie Inlets.

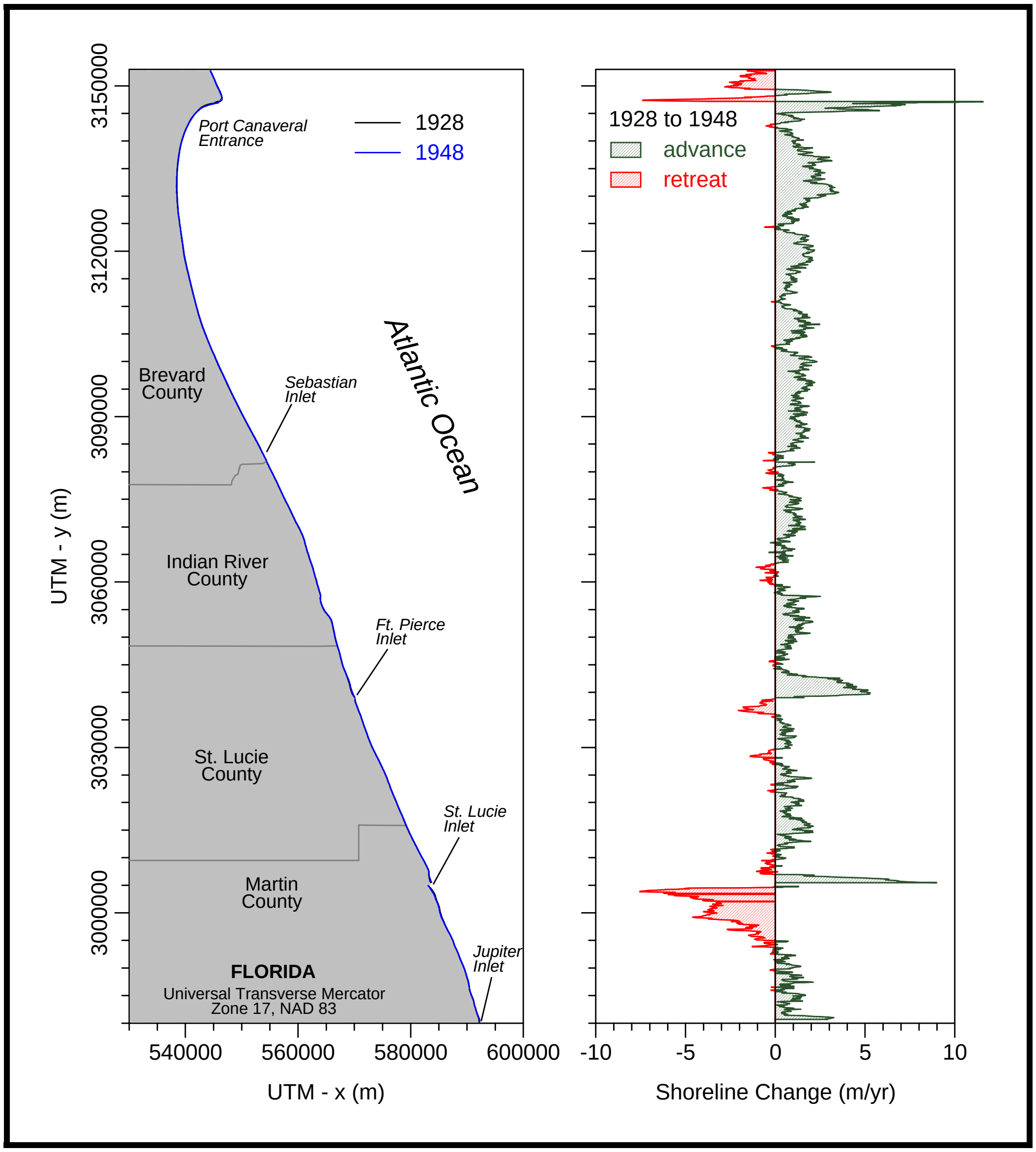

Figure 3-7. Shoreline position and change between False Cape and Jupiter Inlet, FL, 1928 to 1948.

Erosion south of St. Lucie Inlet continued to be a major trend in shoreline response during this time, with recession being dominant from the south side of the entrance to the southern limit of the study area. The maximum erosion rate south of St. Lucie Inlet was approximately 9.5 m/yr, located about 2.4 km south of the entrance.

3.1.3.4 Cumulative Shoreline Position Change (1877/83 to 1970)

Net shoreline change between 1877/83 and 1970 was used to document long-term trends within the study area. The 1877/83 shoreline provided a good baseline for evaluating shoreline change because it represented a time period before the introduction of engineering activities at each of the entrances (i.e., jetty construction, channel dredging, and placement of sand traps). The 1970 shoreline was a good terminal year for long-term comparison because it was the most recent time period that preceded many of the major beach nourishment projects that began to take place in the early 1970s and continue today (see Figure 3-3). As such, shoreline response between these two time periods documented long-term trends that reflect overall patterns of regional change that would be expected to continue in the absence of beach nourishment.

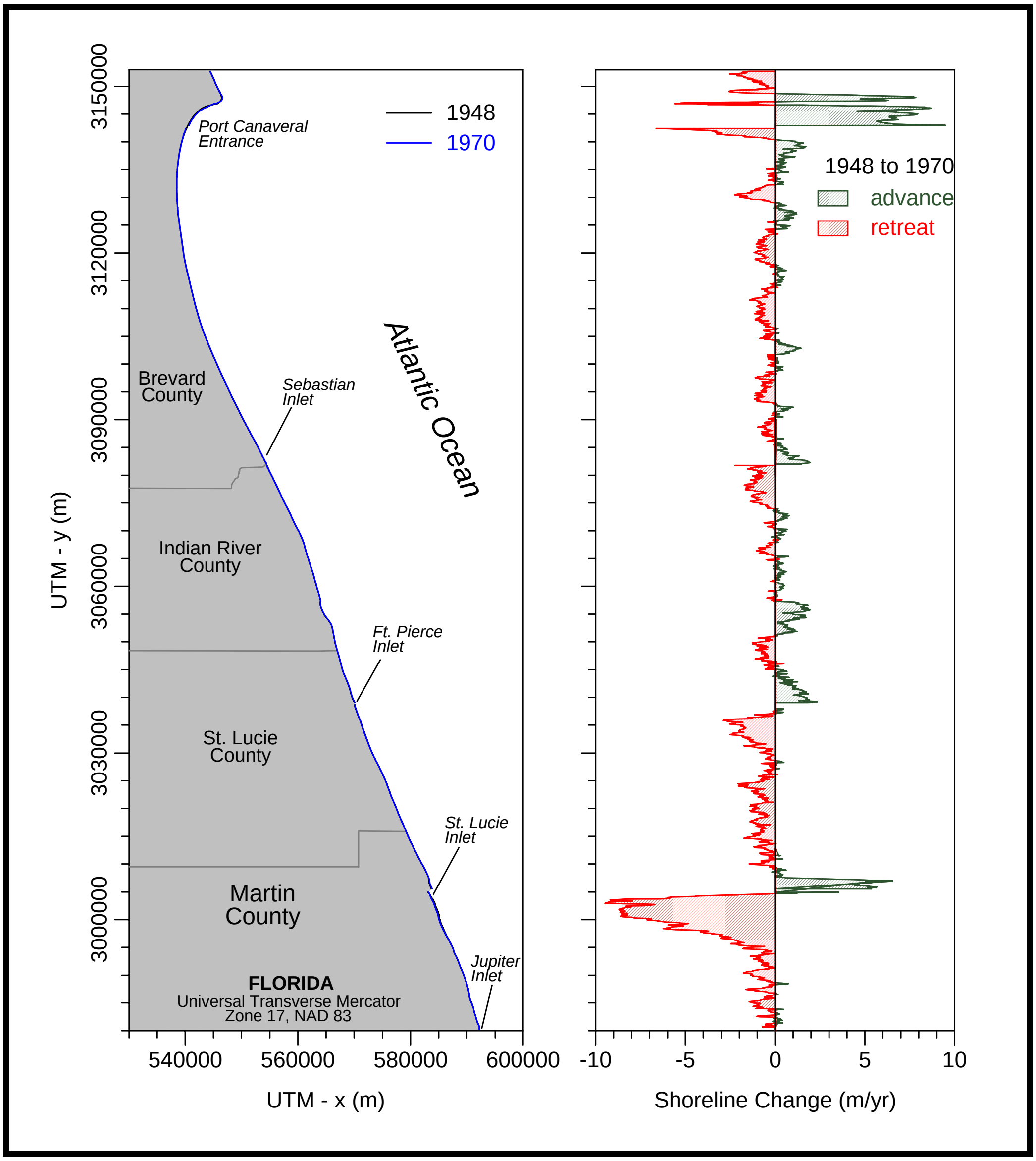

Figure 3-8. Shoreline position and change between False Cape and Jupiter Inlet, FL, 1948 to 1970.

Change trends between 1877/83 and 1970 documented similar erosion and deposition patterns as those observed within the intervening years. Overall, patterns of shoreline advance and retreat were greatest adjacent to entrances (Figure 3-9). This result was consistent with critical erosion areas identified by the FDEP (Figure 3-3). While the overall rate of change was smaller than that observed during shorter time intervals, zones of greatest advance and retreat within the study area continued to be located north of Port

Canaveral and south of St. Lucie Inlet, respectively. Deposition rates of about 5.6 m/yr were recorded north of Port Canaveral while erosion rates of about 9.4 m/yr were recorded south of St. Lucie Inlet. The pattern of change observed south of Port Canaveral between 1948 and 1970 is only visible as a reduction in accretion immediately south of the Port between 1878/83 and 1970, followed by a consistent region of deposition for about 16 km south of the entrance. Shoreline response was relatively stable south of this point until Sebastian Inlet, where the entrance is flanked to the north by deposition and to the south by erosion (Figure 3-9). South of the erosional zone, the shoreline was primarily stable to accretional until south of Fort Pierce Inlet, where the shoreline illustrated net recession for all but a distance of 2.4 km north of St. Lucie Inlet. St. Lucie Inlet is marked by the same north-side deposition and south-side erosion patterns as other entrances, but the magnitude of change was substantially greater for downdrift erosion than at inlets to the north.

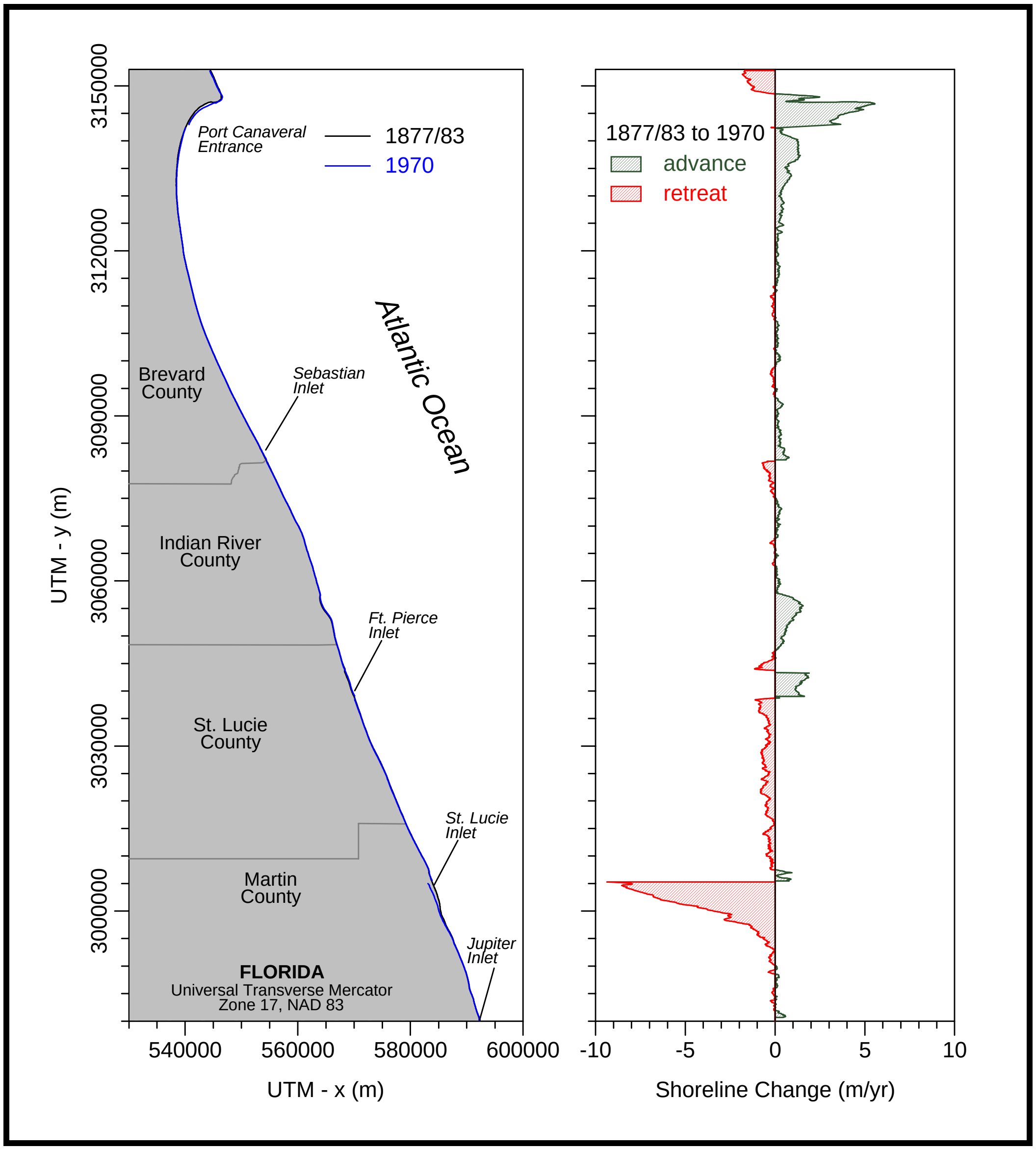

Figure 3-9. Shoreline position and change between False Cape and Jupiter Inlet, FL, 1877/83 to 1970.

3.1.3.5 Recent Shoreline Position Change (1970 to 1996/2002)

The period 1970 to 1996/2002 represents the most recent time interval for quantifying shoreline change, when aerial photography and DGPS surveys were used for recording shoreline position, and beach nourishment was active (see Figure 3-3). This time period was analyzed to identify recent trends in shoreline response to beach nourishment activities and inlet management practices, in addition to natural processes. Locations and volumes of beach fills during this time period (totaling about 21.4 mcm [28 million cubic yards (mcy)] over the total study area) have been included in this analysis to assess factors contributing to change patterns. Trends observed were compared against regions classified as "critically eroding" by the FDEP in 2000 (Figure 3-4). In addition, the effects of using new mapping techniques (e.g., DGPS surveys, improved aerial photo quality, more precise registration methods, and better interpretation techniques) have been taken into consideration. While improvements in shoreline mapping contribute to better quality data sets and potentially more accurate change assessments, comparisons against earlier data sets must consider respective error analyses.

Regional shoreline change trends for 1970 to 1996/2002 are consistent with those observed in previous years. In particular, beaches along the north and south coast of Cape Canaveral showed similar trends of alternating erosion and deposition. Additionally, changes adjacent to four of the inlets illustrated expected erosion and accretion patterns, excluding St. Lucie Inlet, which experienced deposition south of the entrance for the first time. This is particularly important because previous evaluations showed maximum loss for the entire study area along beaches south of St. Lucie entrance. In addition to this shift in trend, some areas that had been experiencing erosion during earlier time intervals and are classified by the FDEP as "critical erosion zones" exhibited deposition during this time interval. Many of these anomalous regions correspond to beach fill areas.

Shoreline change north of Port Canaveral ranged from -5.5 to 7.2 m/yr for this time period. This range is similar to rates observed during previous time intervals, indicating that transport processes in this region remained consistent with long-term trends. South of Port Canaveral, shoreline response was dominated by deposition for a distance of about 13 km, with rates at a maximum of about 4.5 m/yr near the entrance and decreasing gradually to the south. While this trend is consistent with long-term trends observed from 1878/83 to 1970 (Figure 3-9), it deviates significantly from that observed for 1948 to 1970 (preceding short-term interval). Shoreline change from 1948 to 1970 in this region was dominated by recession for about 2.4 km south of the entrance. This change in trend is due in part to beach fills placed south of Port Canaveral. Between 1972 and 2001, approximately 6 mcm (7.8 mcy) of sand was placed along these beaches. Most recently, a beach fill in 2001 covered an area of about 13 km from R-5 to R-50 and consisted of 2.1 mcm (2.8 mcy) of sand. The extent of this beach fill encompassed the entire region of deposition shown in the 1970 to 2002 comparison (Figure 3-10). The trend reversal from the 1948 to 1970 comparison has been influenced by the 1974/75 beach fill and the most recent beach fill. This section of shoreline is part of a 40-km length of shoreline south of Port Canaveral that is considered "critically eroding."

South of Patrick Air Force Base (AFB), shoreline change was dominated by erosion for a distance of about 21 km. Erosion rates in this area were as large as 1.2 m/yr, with an average rate of about 0.5 m/yr. Erosion was more prominent during this time interval than in previous years. Long-term trends document a relatively stable shoreline, with alternating areas of erosion and accretion. Beach fills between 1980 and 2001 were completed along a

6.5-km length of coast at Patrick AFB (R-58 to R-75), totaling 0.9 mcm (1.17 mcy). The most recent fill in 2001, consisting of 414,000 m^3 (541,000 cy) of sand, does not seem to have affected net shoreline change rates significantly. South of this region for about 5 km, shoreline advance was dominant. This deposition zone is associated with the Indialantic beach fill, which was replenished with a total of 1.58 mcm (2.06 mcy) between 1981 and 2002. Of this quantity, 1.03 mcm (1.35 mcy) was placed on the beach during 2002. The effects of the 2002 beach fill are visible along this section of shoreline, as the fill extent parallels that of the deposition zone (Figure 3-10). From this point south to Sebastian Inlet, shoreline recession averages about 0.6 m/yr, which is generally consistent with previous time intervals.

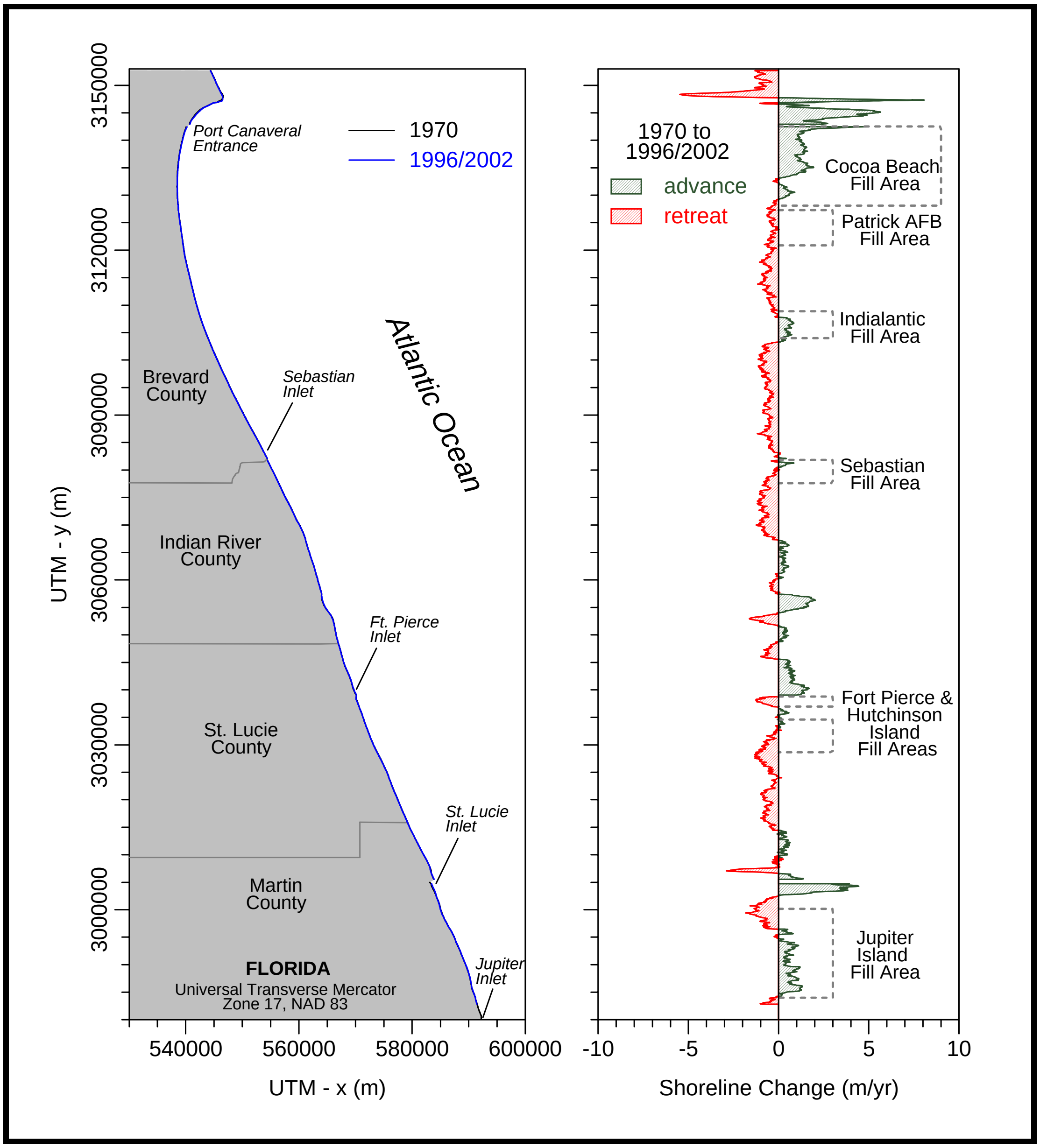

Figure 3-10. Shoreline position and change between False Cape and Jupiter Inlet, FL, 1970 to 1996/2002.

The shoreline immediately south of Sebastian Inlet is primarily erosive for about 16 km, with a small region of deposition immediately south of the entrance. Beach fill activity was conducted south of Sebastian Inlet from 1972 to 1990, totaling about 0.9 mcm (1.17 mcy). The beach fill likely contributed to the small region of deposition that deviates from prior trends. From this point south to Fort Pierce Inlet, shoreline change shows large variability, with moderate rates of erosion and accretion alternating between -1.5 and 2.0 m/yr. Historical trends document similar variability in change patterns along this 45-km section of shoreline. South of Fort Pierce Inlet to St. Lucie Inlet, shoreline recession is dominant, with a minor zone of deposition located approximately 2.3 km south of the entrance. This 3.9-km zone is located immediately south of the Fort Pierce beach fill that was actively nourished from 1971 to 1995. Total beach fill volume during this time period was about 1.45 mcm (1.9 mcy). Southward transport of beach fill likely influenced deposition rates observed in this region.

At St. Lucie Inlet and south along Jupiter Island, shoreline change trends deviate significantly from previous observations. Historically, change along Jupiter Island was dominated by erosion, with minor deposition throughout the region. Although much of the shoreline along Jupiter Island is classified as critically eroding, change trends for the recent time interval illustrate only a small erosional zone south of the inlet for a distance of about 6.4 km. Most of the shoreline illustrates accretion. There are two primary reasons for this trend reversal. The first is associated with construction of the south jetty at St. Lucie Inlet between 1980 and 1982 (Figure 3-11). Subsequent to construction of the south jetty, it seems that erosion trends were abated. Second, beach nourishment projects along Jupiter Island between 1970 and 2002 were quite extensive, including an active 2002 beach fill that is visible in aerial photos used to delineate the shoreline in this region. Total fill volume placed in this region between 1970 and 1996 (excluding the 2002 fill) was about 8.6 mcm (11.3 mcy). Both factors contributed heavily to the significant alteration in shoreline change trends for this time period.

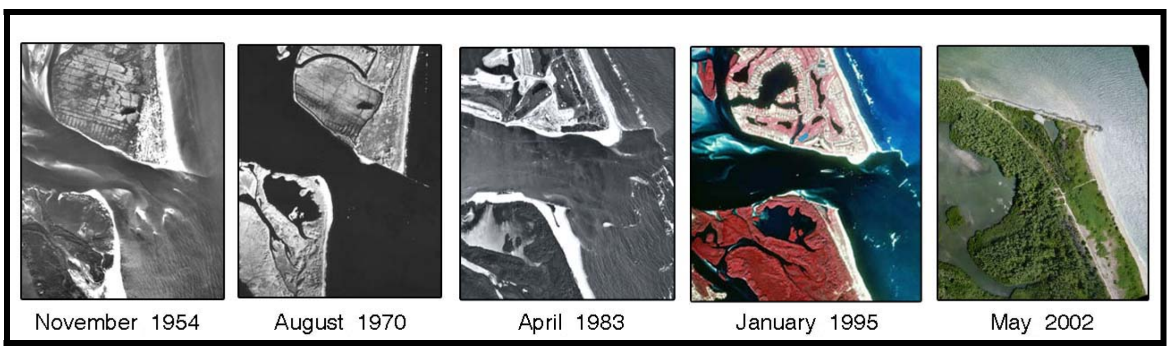

Figure 3-11. Recent shoreline evolution at St. Lucie Inlet, 1954 to 2002.

3.2 NEARSHORE BATHYMETRIC CHANGE

3.2.1 Bathymetric Data Base and Potential Errors

Seafloor elevation measurements collected during historical hydrographic surveys are used to identify changes in nearshore bathymetry for quantifying sediment transport trends relative to natural processes and engineering activities. Five data sets were compiled to document shelf characteristics and examine temporal changes between 1878/83 and 1996. Four data sets were developed from USC&GS Hydrographic surveys (H-sheets), including 1878/83, 1929/30, 1956, and 1964/73. The fifth survey was conducted by the USACE in

1996, and was limited to the offshore region north of Port Canaveral over Canaveral Shoals. Bathymetric surfaces were developed for these time periods to characterize morphologic characteristics of the continental shelf in this region, and change calculations were performed to determine potential infilling rates at each of the borrow sites. Regional temporal comparisons were made for a 200-km coastal segment from the north side of Cape Canaveral (about 16 km north of the tip of Cape Canaveral) to Jupiter Island (about 1.6 km north of Jupiter Inlet), extending offshore to about the 40-m depth contour in the north and to about the 90-m depth contour in the south (southern depths being significantly deeper due to narrowing of the east coast shelf from north to south in this section of Florida [Figure 3-11). Because data density for both time periods decreases with distance offshore, data extents were clipped to areas with the best survey coverage (between 13 and 19 km offshore). The survey sets consist of digital data compiled by the National Geophysical Data Center (NGDC) and analog information (scanned H-sheets) compiled at Applied Coastal using standard image registration and digitizing procedures (Byrnes and Baker, 2003). All data were registered to a common horizontal coordinate system and datum, in this case UTM Zone 17 North and NAD83.

The first regional USC&GS bathymetric survey was conducted in 1878/83 (Table 3-5). Nearshore surveys were mapped at scales of 1:20,000, whereas offshore surveys focused on regional data coverage at a scale of 1:40,000. The density of points in the 1878/83 data set was adequate for describing historical bathymetric features and characterizing coastal and shelf topography, however, more recent surveys (1929/31,1956, 1964/73, and 1996) recorded many more points for describing surface characteristics in sub-sections of the overall area. As such, all quantitative volume change calculations within the borrow sites were made based on data from the 1930/31, 1956, 1964/73, and 1996 surfaces. All change calculations were made using the best available survey data for each site (i.e., greatest point density, most recent time period). Digital data for 1930/31, 1954, and 1964/73 bathymetry are available from the NGDC.

Table 3-5. Bathymetric source data characteristics summary.

Date	Data Source	Comments and Map Numbers
1878/83	USC&GS H-sheets	1878 - Mosquito Inlet to False Cape (H-1409, 1:40,000) 1878/91 - False Cape to Canaveral Shoals (H-1410 1:20,000). 1878 -Cape Canaveral Shoals (H-1411a, 1:20,000). 1881 -Southeast Shoal off of Cape Canaveral (H-1411b, 1:20,000). 1881 -Port Canaveral to Sebastian Inlet (H-1488a, 1:40,000). 1881 -Sebastian Inlet to (H-1488b, 1:40,000). 1882/83 - (H-1523a, 1:40,000). 1882/83 - to Jupiter Inlet (H-1523b, 1:40,000).
1929/31	USC&GS H-sheets	1930 -H-5025 (1:5,000), H-5023(1:10,000:), H-5022, H-5026, H-5027, H-5028, H-5040 (1:20,000), H-5032, H-5034, H-5057, H-5047, H-5116 (1:40,000), H-5029 (1:80,000) 1931 -H-5031 (1:20,000), H-5120 (1:40,000).
1956	USC&GS H-sheets	H-8340 (1:10,000), H-8341, H-8342, H-8343, H-8344 (1:20,000), H-8345 (1:40,000).
1964/73	USC&GS H-sheets	1964 - H-08783 (1:100,000). 1965 - H-8840, H-8839 (1:80,000). 1967 - H-8955, H-8957 (1:20,000). 1973 - H-9344 (1:40,000).
1996	USACE Survey	Digital data provided by the USACE.

Because seafloor elevations are temporally and spatially inconsistent for the entire data set, adjustments to depth measurements were made to bring all data to a common point of reference. These corrections included changes in relative sea level with time and differences in reference vertical datums. Vertical adjustments were made to each data set based on the time of data collection. Depths were adjusted to the North American Vertical Datum (NAVD) of 1988 and were projected to average sea level for the most recent survey. The unit of measure for all surfaces is meters, and final values were rounded to one decimal place before cut and fill computations were made.

To produce continuous surfaces extending seaward from the high-water line, all bathymetric data were combined with temporally consistent shoreline data. An elevation of 2.1 m (NAVD) was assigned to the shoreline based on recent beach profile data obtained from the FDEP and tidal datum reference elevations provided by NGS for stations at Sebastian (8722004) and Fort Pierce (8722212) Inlets. A plot illustrating beach profile examples for 2002 in Brevard County portrays the typical beach shape observed in this region with an identifiable berm crest at elevations ranging from 2.0 to 2.4 m NAVD (Figure 3-12).

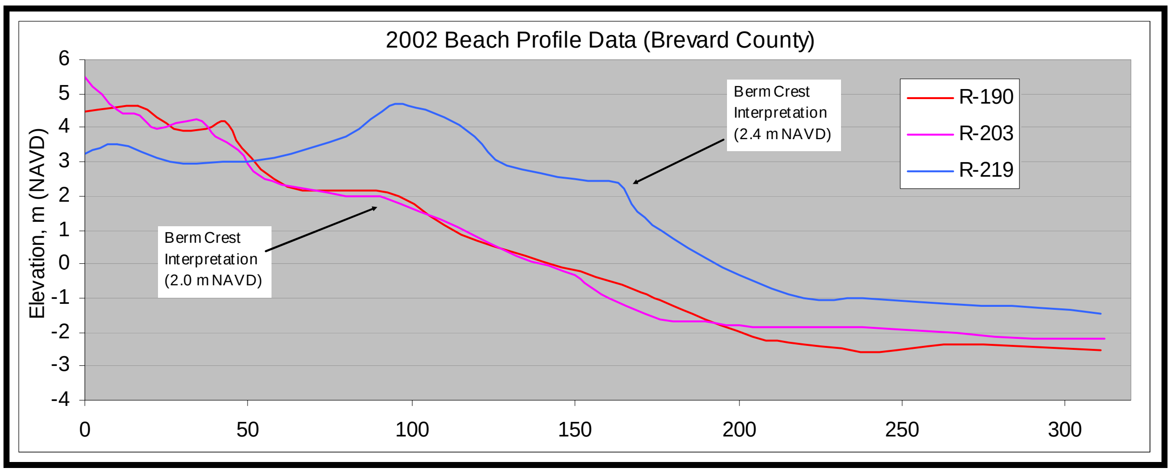

Figure 3-12. Beach profile shape at transects R-190, R-203, and R-219 in southern Brevard County.

As with shoreline data, measurements of seafloor elevation contain inherent uncertainties associated with data acquisition and compilation. It is important to quantify limitations in survey measurements and document potential systematic errors that can be eliminated during quality control procedures. However, most measurement errors associated with present and past surveys are considered random over large areas. As such, random errors cancel relative to change calculations derived from two surfaces. A better method for determining limits of reliability for erosion and accretion areas is to quantify measurement uncertainty associated with bathymetric surfaces. Interpolation between measured points always includes a degree of uncertainty associated with terrain irregularity and data density. The density of bathymetric data, survey line orientation, and magnitude and frequency of terrain irregularities are the most important factors influencing uncertainties in volume change calculations between two bathymetric surfaces (Byrnes et al., 2002). Volume uncertainty relative to terrain irregularities and data density can be determined by comparing surface characteristics at adjacent survey lines. Large variations in depth between survey lines (i.e., few data points describing variable bathymetry) will result in large uncertainties between lines. The computation provides a best estimate of uncertainty for gauging the significance of volume change calculations between two surfaces.

Uncertainty estimates were calculated for the 1878/83, 1929/31, 1956, 1964/73, and 1996 bathymetric surfaces using methods outlined in Byrnes et al. (2002). Multiple sets of line pairs were compared for each time period to represent terrain variability across the surveyed area. Line pairs were chosen that would accurately reflect track line spacing for each survey and the irregularity of prominent geomorphic features in the region. An example of line pairs used for the 1929/31 surface is displayed in Figure 3-13. Lines were established for each time period to overlay survey lines for that year. Bathymetric data were extracted along each line to calculate the variation in elevation between line pairs. Depths were computed at five meter intervals along each line and the absolute values of the differences were averaged to calculate the potential uncertainty for each pair.

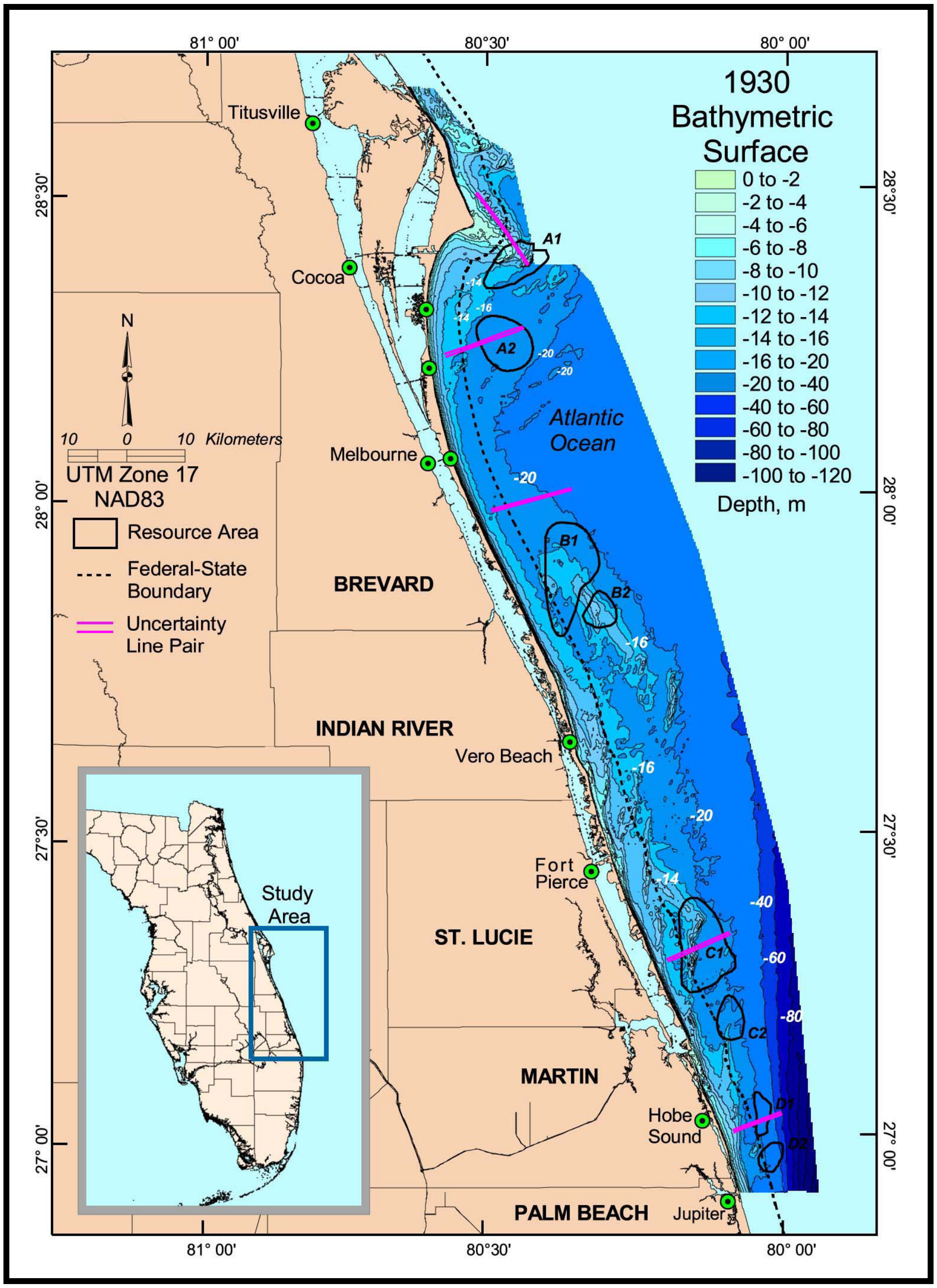

Figure 3-13. Line pairs used to calculate uncertainty for the 1929/31 bathymetric surface.

Results of uncertainty calculations are summarized in Table 3-6. In general, potential uncertainty decreased with time. This was expected due to increases in survey line spacing and better orientation through time. The 0.1 m increase in uncertainty from 1964/73 to 1996 is because most of the 1996 surface encompasses the irregular topography of Canaveral Shoals. As such, an increase in variability for this time period is expected. Combining this information to gauge the impact of potential uncertainties associated with volume change calculations derived from these surfaces resulted in a root-mean-square variation of ± 0.4 m for the 1930/31 to 1964/67 change surface and ±0.4 m for the 1956 to 1996 change surface. For all bathymetric change calculations used for this study, a value range of 0.4 to -0.4 m was used to delineate areas of no determinable change.

Table 3-6. Bathymetric uncertainty estimates.

Data Set	1878/83	1929/31	1956	1964/73	1996
Average Uncertainty (m)	±0.4	±0.3	±0.2	±0.2	±0.3
RMS Error for Change Surfaces					
Data Set	1929/31 to 1964/73			1956 to 1996	
RMS Error (m)	±0.4			±0.4	

3.2.2 Digital Surface Models

Historical bathymetric data provide geomorphic information on characteristic surface features that form in response to dominant coastal processes (waves and currents) and relative sea level change. Comparing two or more surfaces documents net sediment transport patterns relative to incident processes and sediment supply. The purpose for conducting this analysis is to document net sediment transport trends on the shelf surface and to quantify the magnitude of change to verify the significance of short-term wave and sediment transport numerical modeling results. Net sediment transport rates on the shelf were determined using historical data sets to address potential infilling rates at sand borrow sites.

3.2.2.1 1877/83 Bathymetric Surface

Bathymetric data for the period 1878/83 were combined with the 1877/83 shoreline data to create a continuous surface from the high-water shoreline seaward to about the 40-m (NAVD) depth contour. The study area is well defined by the shape of the continental shelf as it narrows from a maximum width of about 48 km just south of Cape Canaveral to a minimum of about 16 km near Jupiter Inlet. As the shelf merges with the north-south oriented Florida-Hatteras Slope, shelf gradient increases noticeably from north to south. Meisburger and Duane (1971) characterized the continental shelf in this region as consisting of three major components, including the inner shoreface zone, the inner shelf plain, and the outer shelf plain. Major characteristics of two of the three shelf regions are visible in the 1878/83 bathymetric surface (Figure 3-14). The narrow shoreface zone extends offshore from the high-water line to about the 10-m depth contour, seaward of which the shelf flattens into the gently sloping inner shelf plain with depths between about 10 and 16 m. East of the inner shelf plain, the seafloor becomes more steeply sloping and irregular as the outer shelf transitions to the top of the Florida-Hatteras Slope. Due to the limited offshore extent of the 1878/83 data set, much of the outer shelf plain is not visible in the 1878/83 bathymetric surface.

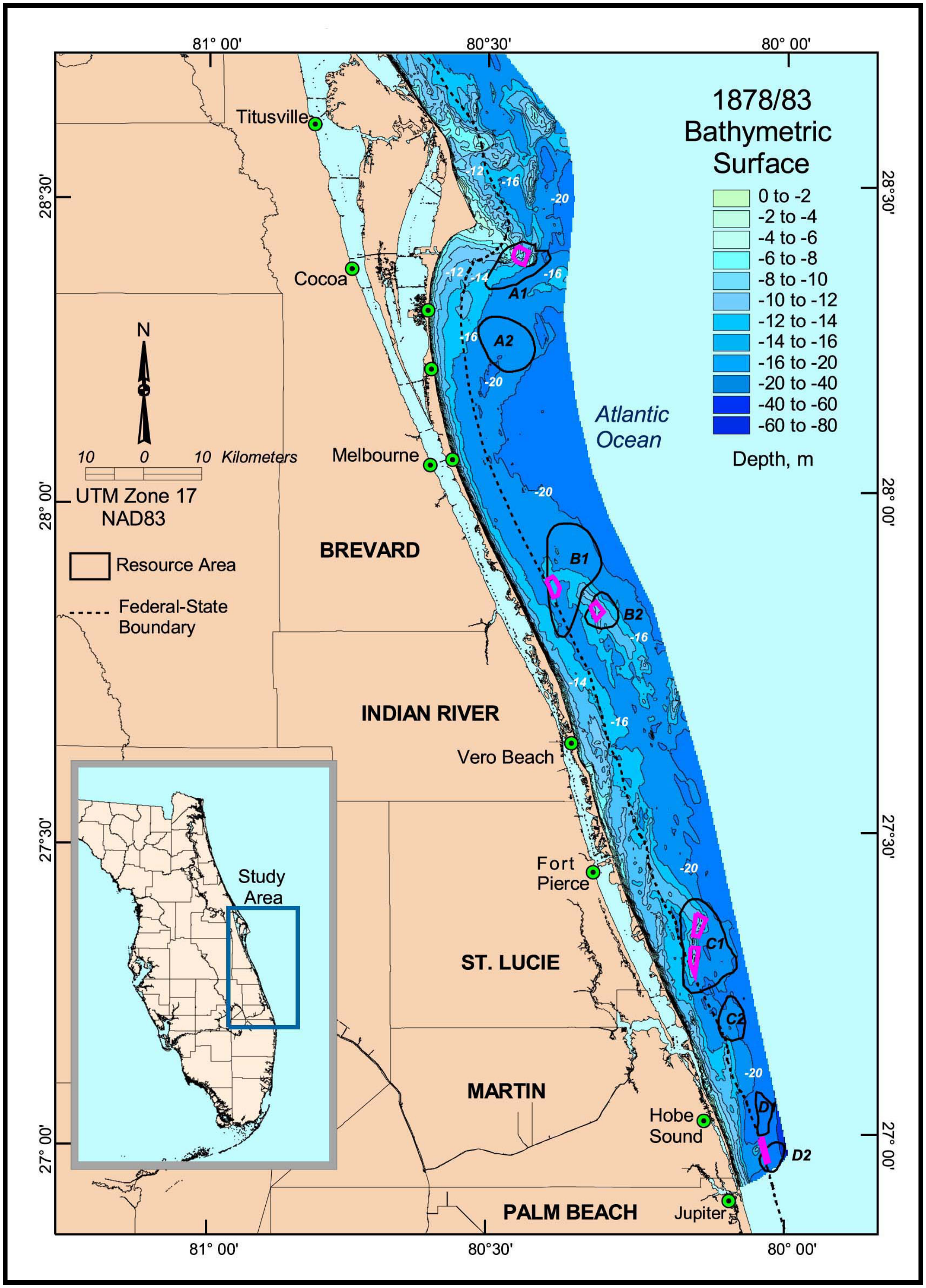

Figure 3-14. Nearshore bathymetry (1878/83) for offshore Florida.

The most prominent geomorphic features throughout the region are offshore shoals and linear sand ridges, from Ohio-Hetzel and Chester Shoals in the north to Gilbert Shoal in the southern portion of the study area (see Figure 3-1). Most of the linear shoals are oriented in a north-south alignment and are most extensive along the inner shelf near Cape Canaveral, Fort Pierce Inlet, and St. Lucie Inlet. Most shoals in the study area are located about 12 to 14 km offshore, landward of the 20-m depth contour, and range in depth from about 8 to 14 m. Bethel Shoal is located farther offshore, at a distance of about 18 km. Many of the shoals visible on the 1878/83 surface exist seaward of the Federal-State Boundary, creating ideal locations for potential sand borrow sites for beach nourishment.

A number of shore-attached ridges have been documented adjacent to the present-day location of Fort Pierce Inlet (Figure 3-14; McLaren and Hill, 2002). While none of the present-day inlets were naturally open to the Atlantic Ocean in their current positions during the 1877/83 shoreline survey, a naturally occurring opening north of the present-day location of Fort Pierce Inlet was evident in the 1877/83 and an earlier 1860s shoreline survey, which may have had influence on the formation of shore-attached sand ridges and shoals within this region (McBride and Moslow, 1991).

The morphology of the continental shelf varies considerably from north to south. Adjacent to Cape Canaveral, topography is highly irregular, with large shoals extending southeast from False Cape and Cape Canaveral (Figure 3-15). Large shoals, ridges, and channels exist along the shelf surface adjacent to the Cape from the shoreface to about 12 km offshore. The alignment of ridges paralleling the Cape shoreline and extending southeast from the foreland is indicative of littoral processes controlling the formation of these features. Sediment eroded from northern beaches is transported southeast into the ridge-shoal complex, creating linear features that migrate in a step-wise fashion to the south and east, creating a highly irregular inner shelf surface. The shoal system extending from Cape Canaveral is generally very shallow, with depths ranging from about 3 to 12 m.

South of the Canaveral shoal system, shelf topography becomes more subdued as it flattens toward Canaveral Bight (Figure 3-15). Much of the study area between Port Canaveral and Sebastian Inlet is primarily flat, lacking the variable topography present for the shoal complex to the north. Shelf orientation parallels the shoreline in this region and generally deepens from a depth of about 12 m at the shoreface to about 40 m over a distance of about 23 km. From Sebastian Inlet to Jupiter Inlet, shelf morphology again becomes more irregular, with numerous north-south trending shoals dominating the structure of the shoreface and the inner shelf (Figure 3-16).

Most sand resource areas identified for this study are associated with shoals visible on the 1878/83 surface, including Southeast Shoal (A-1), Thomas Shoal (B-1 and B-2), St. Lucie Shoal (C-1), and Gilbert Shoal (C-2). Excluding Thomas Shoal, each of these has been characterized previously by ICONS as containing material suitable for beach fills (Figure 3-17; Meisburger and Duane, 1971; Field and Duane, 1974). Thomas Shoal was not characterized as extensively as other shoals during the ICONS study, however, the suitability of surrounding shoals indicates that this shoal would likely be a good candidate as a borrow site as well.

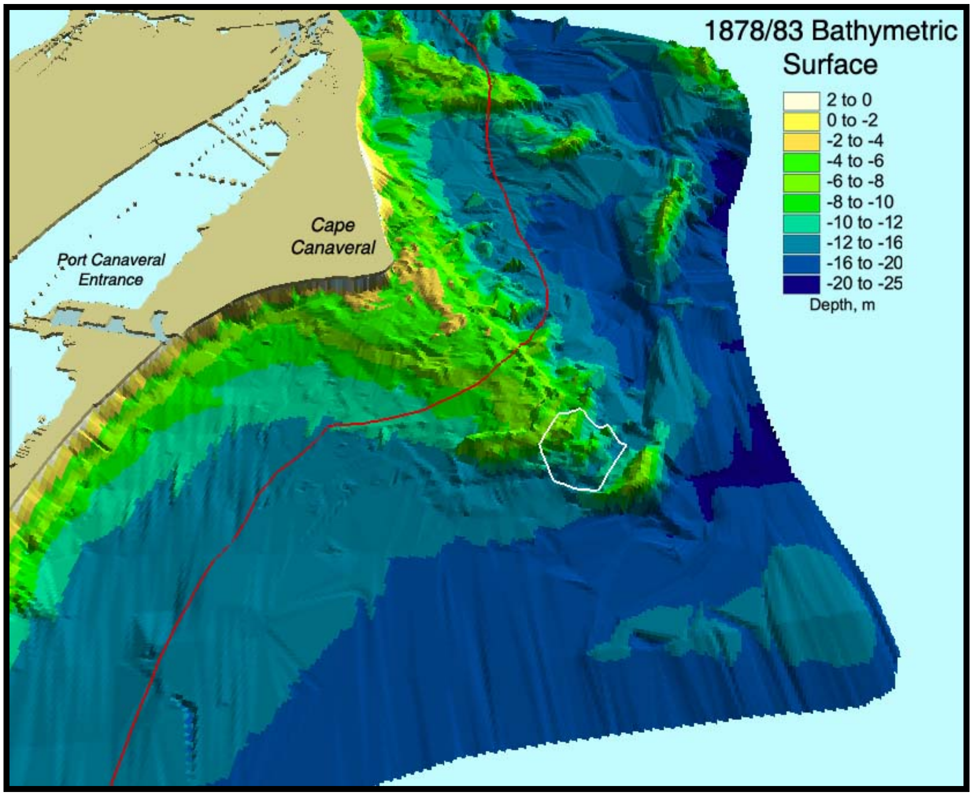

Figure 3-15. Three-dimensional view of Canaveral Shoals, 1878/83.

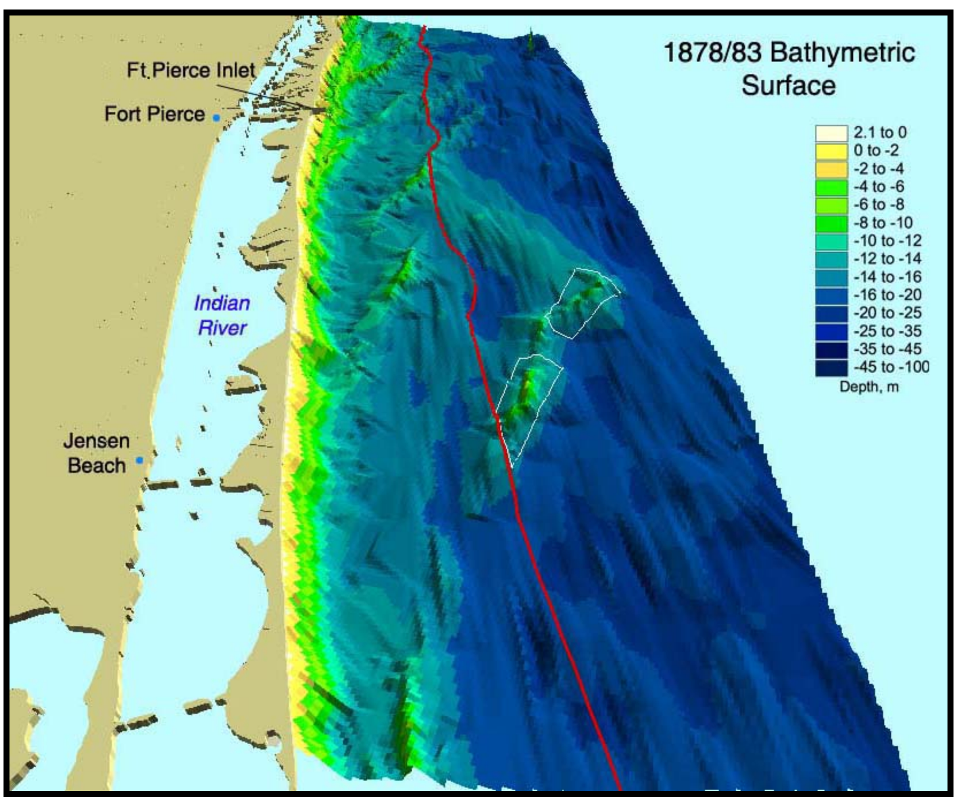

Figure 3-16. Three-dimensional view of shoal field near Ft. Pierce Inlet, 1878/83.

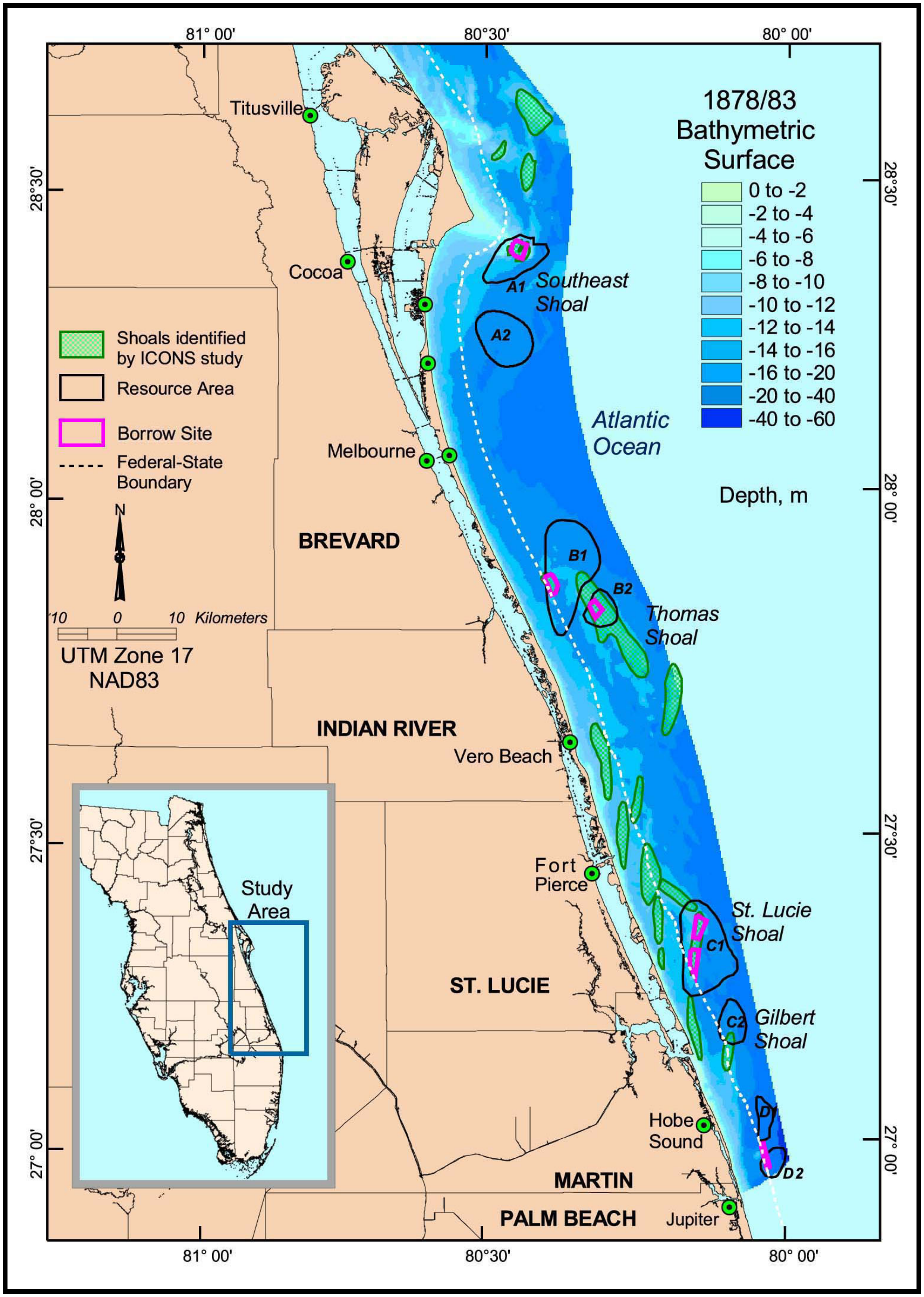

Figure 3-17. Nearshore bathymetry (1878/83) with ICONS shoals identified.

3.2.2.2 1929/73 Bathymetric Surface

Bathymetric data for the years 1929/31, 1956, and 1964/73 were compiled to create a continuous surface representing the most recent time period for regional bathymetric characterization. Most data are composed of the 1956 and 1964/73 data sets, but some regions lacking sufficient data coverage from either of those time periods were filled with data from the 1929/31 surveys to provide complete coverage for the region. Bathymetric data were combined with shoreline data that were temporally coincident with the survey time period abutting the coast. Major characteristics of this bathymetric surface are similar to those of the 1878/83 surface with a couple of exceptions (Figure 3-18). First, the number of data points describing geomorphic features was greater, thus enabling better characterization of the numerous shoals and linear sand ridges. Second, the combination of these data sets allowed for increased data coverage seaward of the 1878/83 data set, providing better characterization of the outer shelf surface.

Overall, general characteristics of the bathymetric surface are similar to those of the previous time period. The shape, size, and position of sand ridges are consistent for both surfaces, with a few changes visible in the 1929/73 bathymetry. First, the shoreface fronting Cape Canaveral displayed some noticeable differences from the previous time period. The shelf surface north of the Cape is visibly steeper along the shoreline, which is consistent with sediment transport and shoreline change trends illustrating long-term erosion for this region (Figure 3-19). Additionally, the area south and east of Cape Canaveral showed noticeable shoaling, indicated by seaward advance of the 4-m depth contour. While the size and shape of the subaqueous spit platform surrounding the Cape remained relatively unchanged, depths over the feature generally decreased. This result is consistent with shoreline change and sediment transport trends, which showed constant deposition on the southern shoreline of the Cape. Additionally, the inner shelf between Port Canaveral and Sebastian Inlet shoaled somewhat during this time period, as bathymetric depressions evident landward of the 20-m depth contour on the 1878/83 surface were significantly diminished on the 1929/73 surface. Seaward of the 20-m depth contour, some bathymetric highs visible on the 1929/73 surface were absent from the 1878/83 surface. This may be due in part to better data coverage, but it is a noticeable change from the previous data set. The southern portion of the study area has noticeable improvements in shoal and ridge definition, which are visible at the shore-attached ridges in the vicinity of Fort Pierce and at offshore shoals (Figure 3-20).

3.2.2.3 1996 Bathymetric Surface

A 1996 bathymetric survey acquired by the USACE was used to characterize recent bathymetry adjacent to Cape Canaveral. Although the extent of this data set was limited to the offshore area north of Port Canaveral, the density of data points provided a good source of additional information for assessing sediment transport patterns in the area. The general characteristics of the seafloor offshore Cape Canaveral were very consistent with those of the 1929/73 data set, with some changes apparent along the shoreline and on the shoreface (Figure 3-21). The shape and size of shoals were very similar to those documented in previous time periods, with some lengthening of linear features throughout the subaqueous spit complex (Figure 3-22). Extension of the terminal point of the Cape was visible at the shoreline, and seaward expansion of the 4-m depth contour was noticeable.

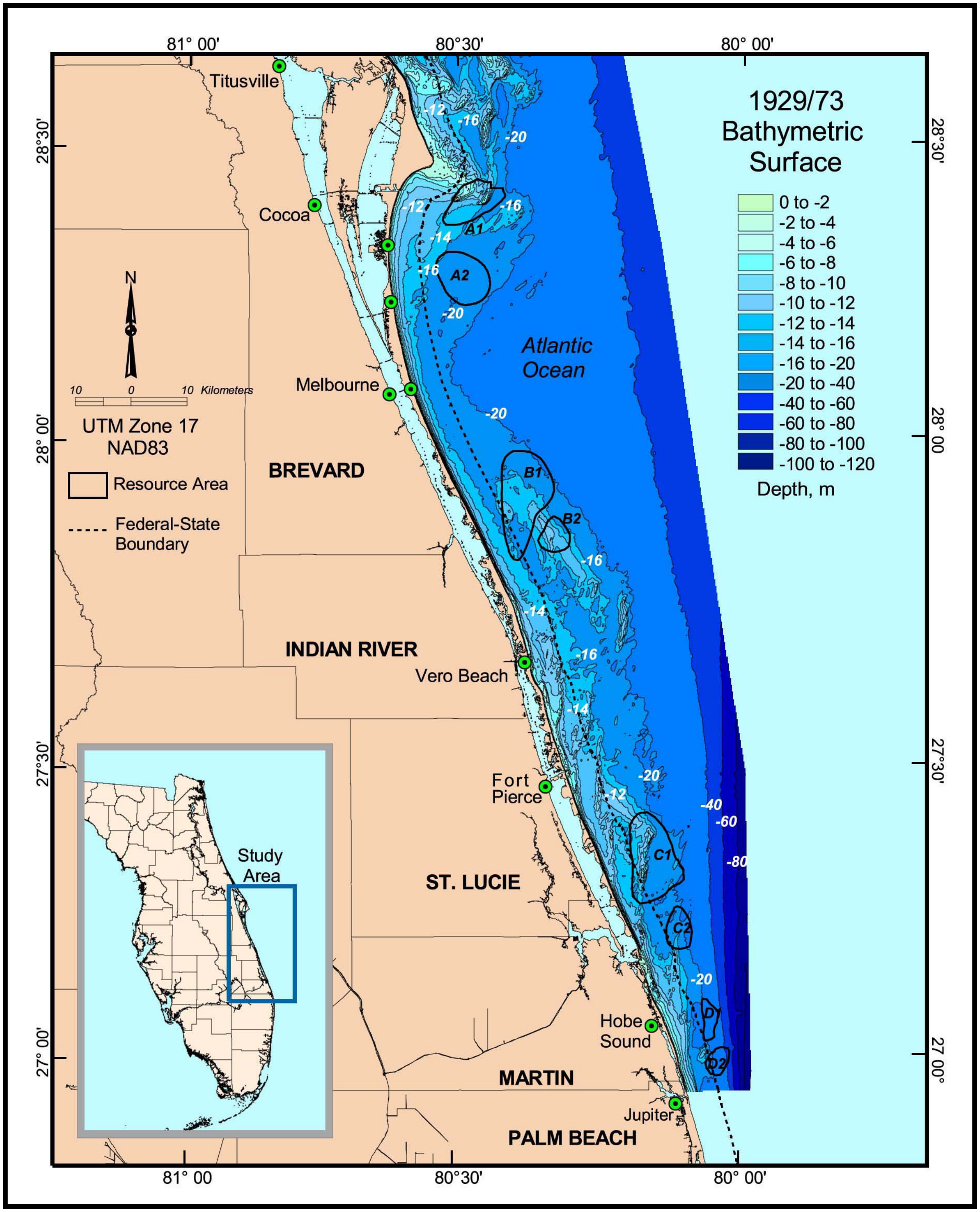

Figure 3-18. Nearshore bathymetry (1929/73) for offshore Florida.

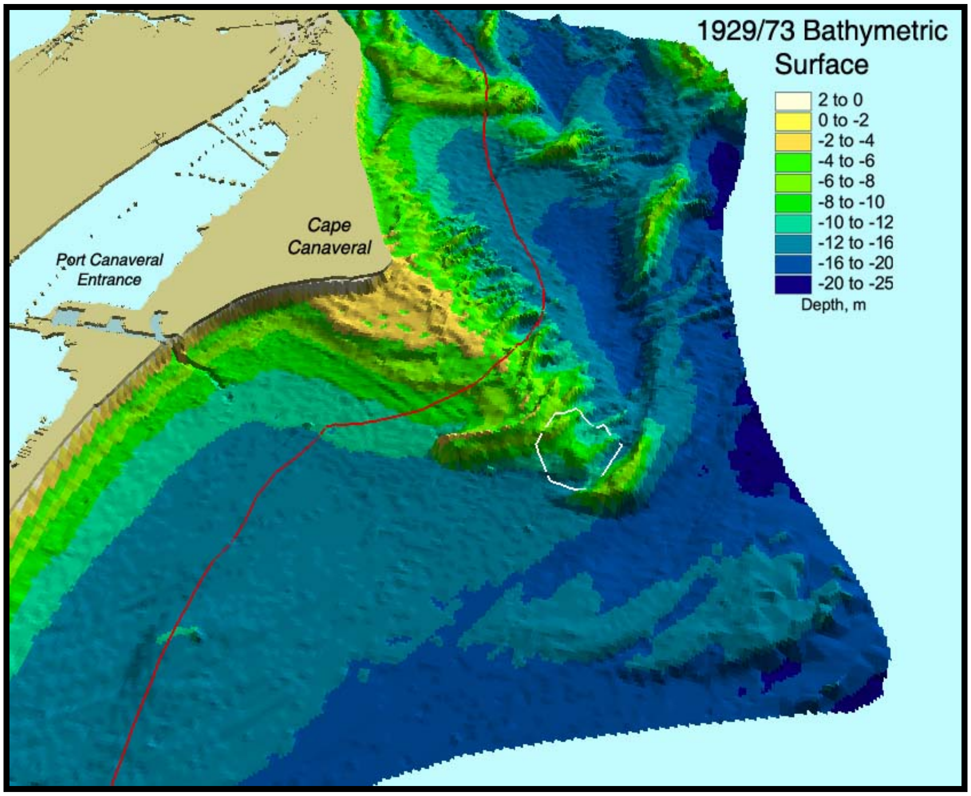

Figure 3-19. Three-dimensional view of Canaveral Shoals, 1929/73.

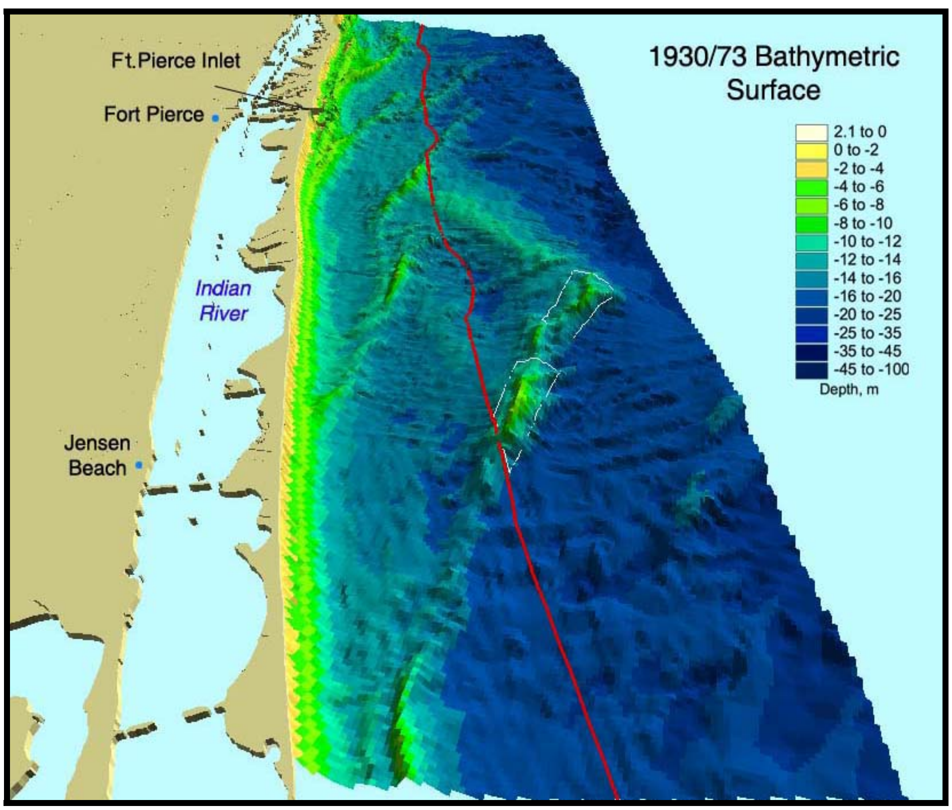

Figure 3-20. Three-dimensional view of shoal field near Ft. Pierce Inlet, 1930/73.

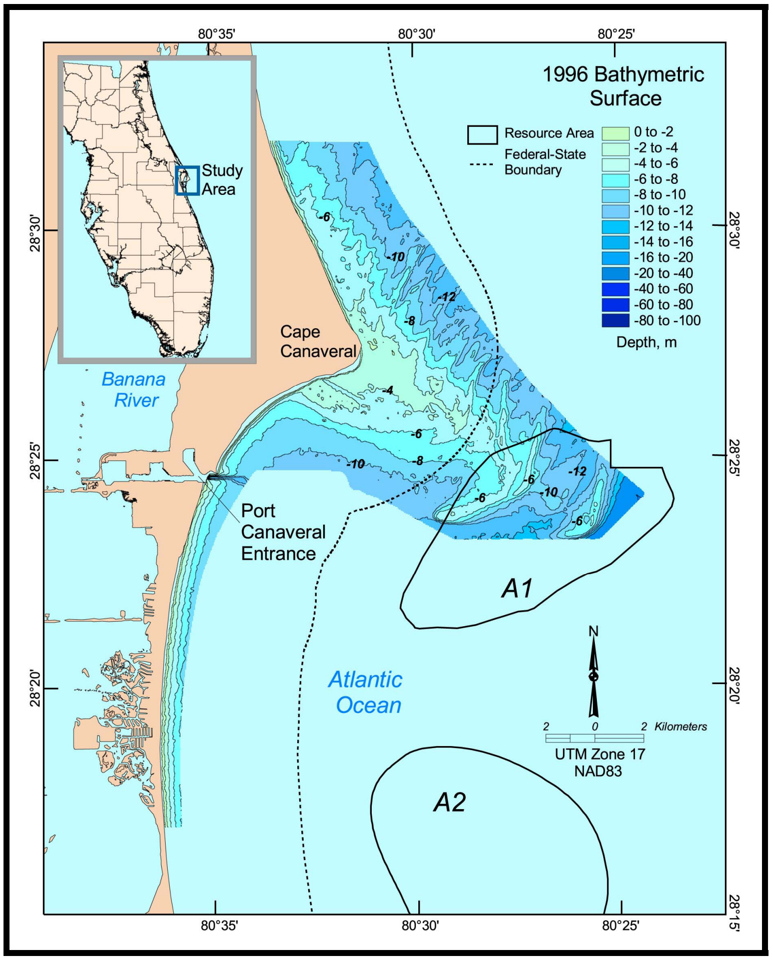

Figure 3-21. Nearshore bathymetry (1996) for offshore Florida.

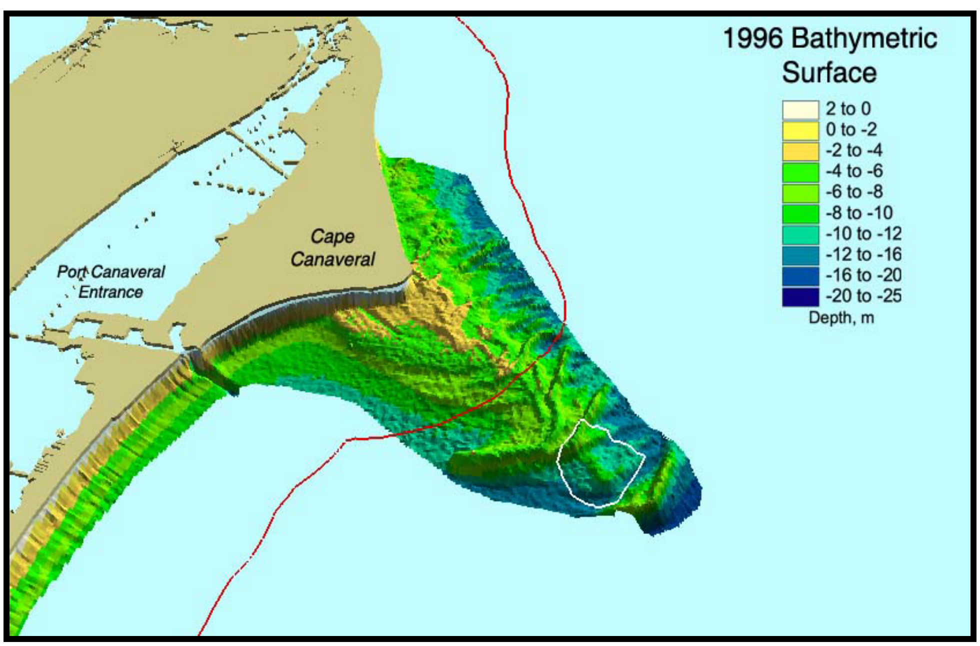

Figure 3-22. Three-dimensional view of Canaveral Shoals, 1996.

3.2.3 Shelf Sediment Transport Dynamics

Although general characteristics of the bathymetric surfaces are similar for 1878/83, 1929/73, and 1996, a digital comparison of these surfaces yielded a difference plot that isolated areas of erosion and accretion for documenting sediment transport patterns and quantifying trends. Due to variation in data coverage at each borrow site, different time periods were used to quantify change trends depending on which data sets were determined to be best for comparison at each site. A comparison between 1956 and 1996 data sets was used for quantifying transport rates at Borrow Site A1, and the 1929/31 and 1964/73 data sets were used for determining rates at Sites B1 through D2. Two regional change plots were generated for the study area. A bathymetric change plot from 1956 to 1996 extended from the northern boundary of the study site to the north side of Port Canaveral (Figure 3-23), and a comparison between 1929/31 and 1929/73 was generated for the offshore area south of Port Canaveral to the southern boundary of the study area (Figure 3-24).

3.2.3.1 Bathymetric Change Adjacent to Cape Canaveral: 1956 to 1996

Bathymetric change observed between 1956 and 1996 along the inner shelf adjacent to Cape Canaveral depicts a high-energy environment within this topographically variable region. South-directed longshore transport around Cape Canaveral mobilizes substantial quantities of sand near the coastline and on the upper shoreface, resulting in subaqueous spit growth along the down-drift margin of the Cape and shoal migration, illustrated as areas of erosion (yellow to red) and deposition (light to dark blue) on Figure 3-23. Polygons of erosion and deposition generally follow contour shapes defined by shoals and troughs. Alternating zones of accretion and erosion reflect the migration of sand ridges. Deposition zones to the southeast of erosion areas indicate dominant south-directed transport processes. Clearly defined linear regions of erosion are flanked to the southeast by large linear deposits, reflecting transport trends under incident wave and current processes. Significant deposition along the beach south of Cape Canaveral indicates high rates of sediment transport from beaches and shoals. Bathymetric change is greatest along the exposed northeast region of the study area, with magnitudes decreasing in the protected southwest region, as wave energy dissipates over Canaveral Shoals. Shelf bathymetry exposed to waves from all directions is more variable than that to the southwest, where low relief features reside within Canaveral Bight. Shelf bathymetry south of Canaveral Shoals and north of Thomas Shoal (Figure 3-19) is relatively featureless, reflecting the protection provided by Canaveral Shoals from east and northeast waves.

Processes observed in the change comparison between the 1956 and 1996 data sets are supported by data developed as part of the Cape Canaveral ICONS study. Using seismic reflection profiles and sediment samples, the study identified active shoal reworking through abrasion and transport in this region. Bottom profile comparisons made for the ICONS study indicate that since 1898, all shoals associated with Cape Canaveral have broadened, thickened, and become shallow. Additionally, shoals landward of the 6-m depth contour have shifted slightly southeast (Field and Duane, 1974), which is consistent with trends observed in Figure 3-23.

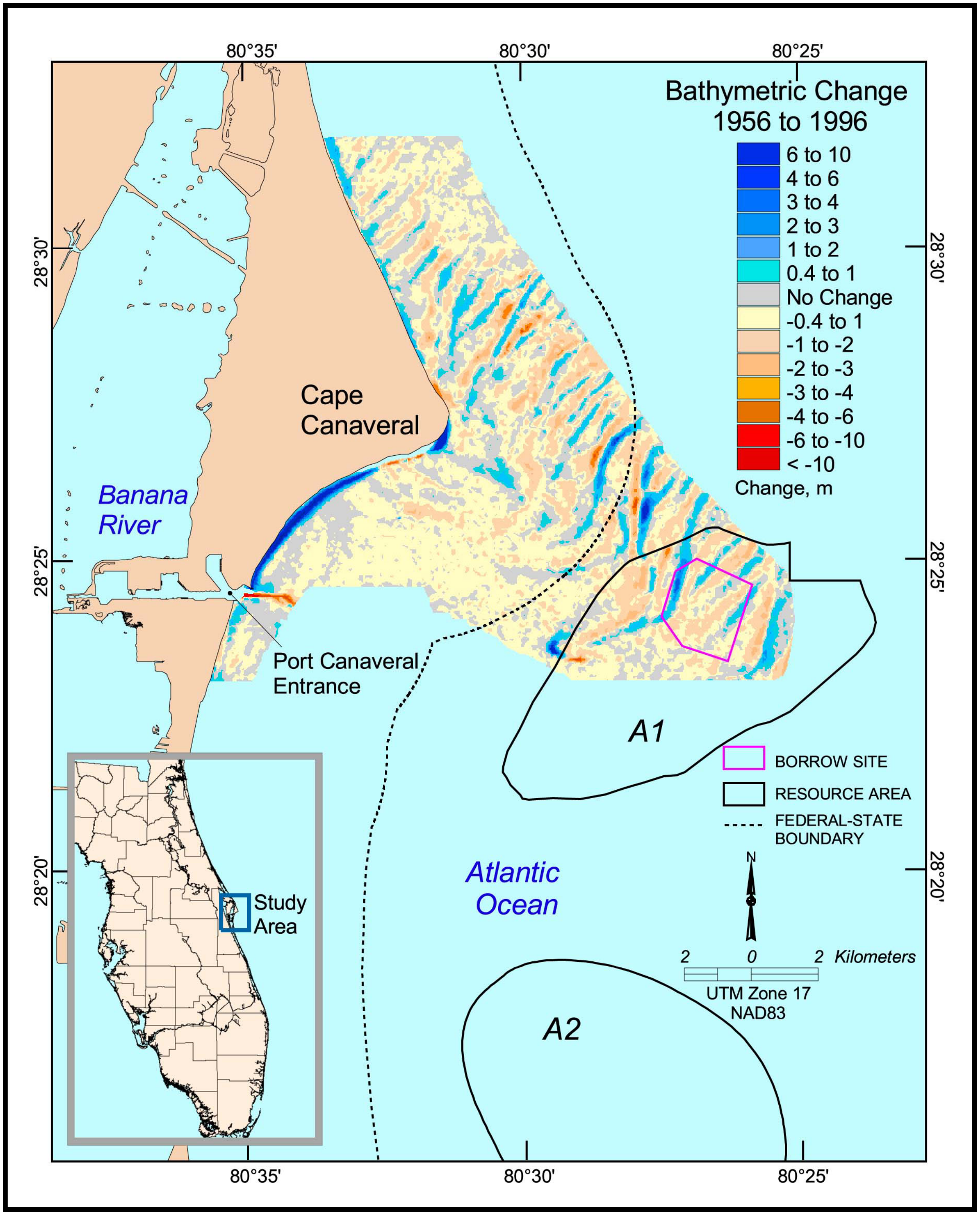

Figure 3-23. Nearshore bathymetric change between 1956 and 1996 for offshore Cape Canaveral.

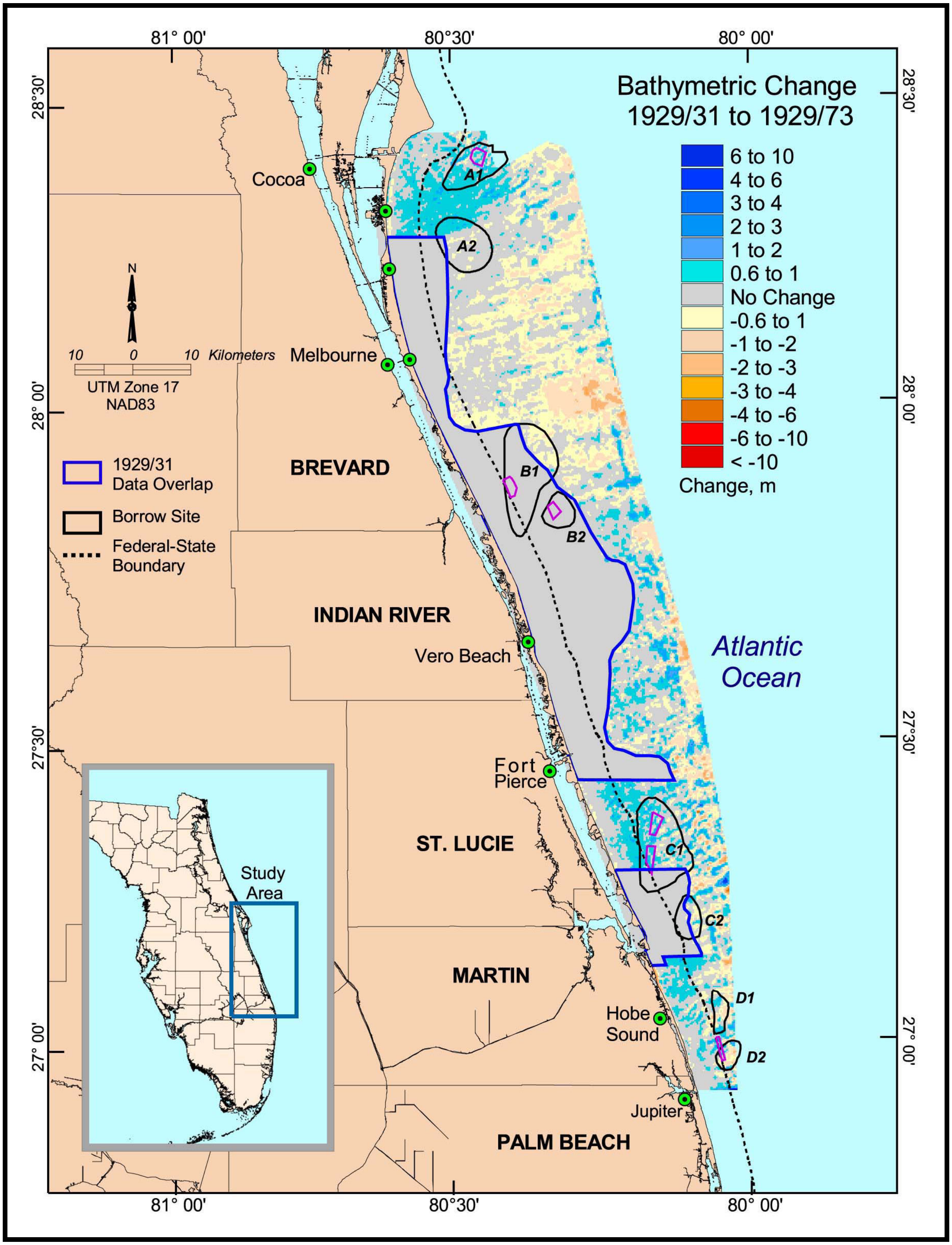

Figure 3-24. Nearshore bathymetric change between 1929/31 and 1929/73 for offshore central east Florida.

The depth over shoals seaward of Cape Canaveral is relatively shallow, representing a viable region for sand resources. Canaveral shoals have been identified by Field and Duane (1974) as suitable sources for beach nourishment projects based on textural similarities with beach sands and thickness of deposits. Samples documented a median grain size along Southeast Shoal (associated with Borrow Site A-1) of 0.31 to 1.12 mm, with a standard deviation of 1.46 to 2.1 mm (Field and Duane, 1974). They estimated that a minimum of 11.6 mcm of sand was highly suitable for beach nourishment.

3.2.3.2 Bathymetric Change South of Port Canaveral: 1929/31 to 1929/73

Transport processes affecting bathymetric change between 1929/31 and 1929/73 south of Port Canaveral diverge from those observed to the north. Wave and current processes driving sedimentation and shoal migration adjacent to Cape Canaveral are reduced for shelf areas south of Port Canaveral to Jupiter Inlet. Lack of quality data at some nearshore areas for this time period prevented complete bathymetric change comparison for the entire region, which is illustrated on the change plot (Figure 3-24). The area where change could not be evaluated exists on the inner shelf between Patrick AFB and Fort Pierce Inlet, most of which exists outside the sand resource areas. Only change calculations for Resource Areas B1 and B2 were affected by the lack of data, and in these cases, change rates for adjacent areas were considered analogous for borrow sites in Areas B1 and B2. Bathymetric change comparisons were available for most shoal areas being evaluated for sand resource extraction impacts.

Deposition was prominent along the inner shelf offshore Port Canaveral and Cocoa Beach, within the low relief area protected by Canaveral Shoals. Sediment transported south over Canaveral Shoals may be depositing material in this area as nearshore wave and current processes diminish south of Cape Canaveral. Depositional zones also were prominent in the shoal regions along the inner shelf from Fort Pierce south to Jupiter Inlet. An evaluation of shelf sediment sources from Cape Canaveral south to Palm Beach was completed under the ICONS study (Meisburger and Duane, 1971). Fine-grained sediments found on the shelf south of Canaveral Shoals is indicative of reduced sand transport to this area from the north. Because net littoral transport is from north to south, sediment supply from the south also is ruled out as a primary source. The ICONS study concluded that most shelf sediment is locally produced and only small quantities of sediment are being supplied to the shelf surface south of Canaveral Shoals from adjacent shelf areas or from the littoral drift system. Recent sediment samples collected offshore Fort Pierce Inlet indicated high quantities of carbonate and shell fragments (Figure 3-2), which is consistent with the sedimentary analysis completed under ICONS in 1971. It is likely that much of the deposition documented on the 1929/31 to 1929/73 change surface resulted from local growth of biogenic material.

3.2.4 Magnitude and Direction of Change

Patterns of seafloor erosion and accretion on the continental shelf seaward of the central east Florida coast documented the net direction of sediment transport throughout the study area (Figures 3-23 and 3-24). For the period 1877/83 to 1929/73, net sediment movement is from north to south. This direction of transport is consistent with historical shoreline change trends and channel dredging practice at entrances along the Florida coast (any sidecasting, nearshore, or offshore dumping is to the south of inlets). It also is consistent with the locations of FDEP designated zones of “critical erosion” at inlets (Figure 3-4). Although overall trends are helpful for understanding potential impacts of sand extraction from the OCS, the specific purpose of historical bathymetric change assessment is to quantify sediment erosion and accretion and to derive infilling rates specifically related to potential sand extraction sites.

Potential infilling rates at resource areas were evaluated by comparing deposition and erosion rates at and adjacent to proposed borrow sites. For all volume change calculations, the maximum of either erosion or deposition was used as an indicator of potential infilling, assuming that the larger of these two reflects the rate at which sediment would be available for transport (and infilling) at each site. To accurately assess the magnitude of change across the region, transport rates calculated for individual sites were normalized to the area of the largest borrow site polygon. As such, reasonable comparisons could be made between transport rates calculated throughout the study area.

For Sand Resource Area A1, volume change between 1956 and 1996 was used as an indicator of potential transport (infilling) rates (Figure 3-23). Seafloor erosion over the 40-yr period ranged from about 88,000 to 119,000 m^3/yr (Table 3-7). For Areas B1 and B2, potential infilling rates were calculated at areas located northeast and east of the borrow sites due to lack of data near the actual sites (Figure 3-24). Change between 1930 and 1967 for the site in Area B1 ranged from 38,000 to 64,000 m^3/yr, and change for the site in B2 ranged from 61,000 to 98,000 m^3/yr. Infilling rates at both borrow sites located within Area C1 ranged from 76,000 to 113,000 m^3/yr. Rates for Area D2 ranged from 72,000 to 104,000 m^3/yr. As expected, highest infilling rates are located seaward of Cape Canaveral. This reflects a more dynamic offshore environment near the Cape. Again, this calculation assumes that sediment eroded from areas nearby potential borrow sites reflects the rate at which material would be available for infilling the borrow sites. Further consideration should be given to local sources of shell material at southern sites when addressing infilling rates for specific projects in those areas. Rates of production of biogenic material are unknown, and their contribution to deposition in this area is undetermined. Dredging geometry for each potential borrow site (depth to width to length), as well as the type of sediment available for infilling, are controlling factors for determining sediment infilling.

Table 3-7. Potential infilling rates at borrow sites.

Site	Normalized Infilling Rate (m^3/yr)
A1	88,000 to 119,000
B1	38,000 to 64,000
B2	61,000 to 98,000
C1 North	87,000 to 113,000
C1 South	77,000 to 112,000
D1	72,000 to 104,000

3.2.5 Net Longshore Sand Transport Rates

Shoreline and bathymetric change data documented net deposition north of inlets and net erosion along beaches south of inlets throughout the study area (see Figures 3-8 and 3-23). Bathymetric data coverage was not sufficient on a regional scale to quantify deposition and erosion patterns seaward of the high-water shoreline to closure depth. However, bathymetric change information is available for the area between Cape Canaveral and Port Canaveral Harbor. In combination with dredging records for Port Canaveral, net longshore transport was estimated at about 236,000 m^3/yr (308,000 cy/yr) just south of Cape Canaveral (Kraus et al., 1999). South of Port Canaveral entrance, net transport decreases to about 119,000 m^3/yr (155,000 cy/yr). According to Walton (1976) and Dean and O'Brien (1987), the net littoral transport rate remains relatively constant until Fort Pierce Inlet, at which point, net transport rates increase from approximately 140,000 to 184,000 m^3/yr (183,000 to 240,000 cy/yr) south to Jupiter Inlet.

3.3 SUMMARY

Shoreline position and nearshore bathymetric change documented four important trends relative to study objectives. First, the predominant direction of sediment transport on the continental shelf and along the outer coast between Cape Canaveral and Jupiter Inlet is north to south. The greatest amount of shoreline change in this study was associated with beaches adjacent to Cape Canaveral, Port Canaveral Entrance, and beaches south of St. Lucie Inlet.

Second, the most dynamic features within the study area, in terms of nearshore sediment transport are the beaches and shoals associated with Cape Canaveral. Areas of significant erosion and accretion are documented between 1956 and 1996 at Cape Canaveral, reflecting wave and current dynamics and the contribution of littoral sand transport from the north to shoal and spit migration. Depositional zones also are prominent in the shoal regions along the inner shelf from Fort Pierce south to Jupiter Inlet. Large quantities of carbonate and shell fragments observed in sediment samples collected from shoals in this region indicate that much of the deposition in this portion of the study area may have been locally produced.

Third, alternating bands of erosion and accretion documented between 1956 and 1996 at Cape Canaveral illustrate steady reworking of the upper shelf surface as sand ridges migrate from north to south. The process by which this is occurring at Area A1 suggests that the borrow site in this region would fill with sand transported from the adjacent seafloor at rates ranging from 88,000 to 119,000 m^3/yr. Areas of erosion and accretion documented between 1929/31 and 1929/73 between Port Canaveral Entrance and Jupiter Inlet indicate the amount of sediment available for infilling sites south of Port Canaveral Entrance is between 38,000 and 113,000 m^3/yr.

Finally, net longshore transport rates determined from seafloor changes in the littoral zone between Cape Canaveral and Port Canaveral entrance, in conjunction with dredging records for Port Canaveral entrance, indicate maximum transport rates near Cape Canaveral, with lower rates south of the entrance. Net longshore transport north of Port Canaveral entrance was estimated at about 236,000 m^3/yr. South of the Port, rates have been estimated to range from 119,000 m^3/yr immediately south of the entrance to 140,000 to 184,000 m^3/yr between Fort Pierce and Jupiter Inlets.